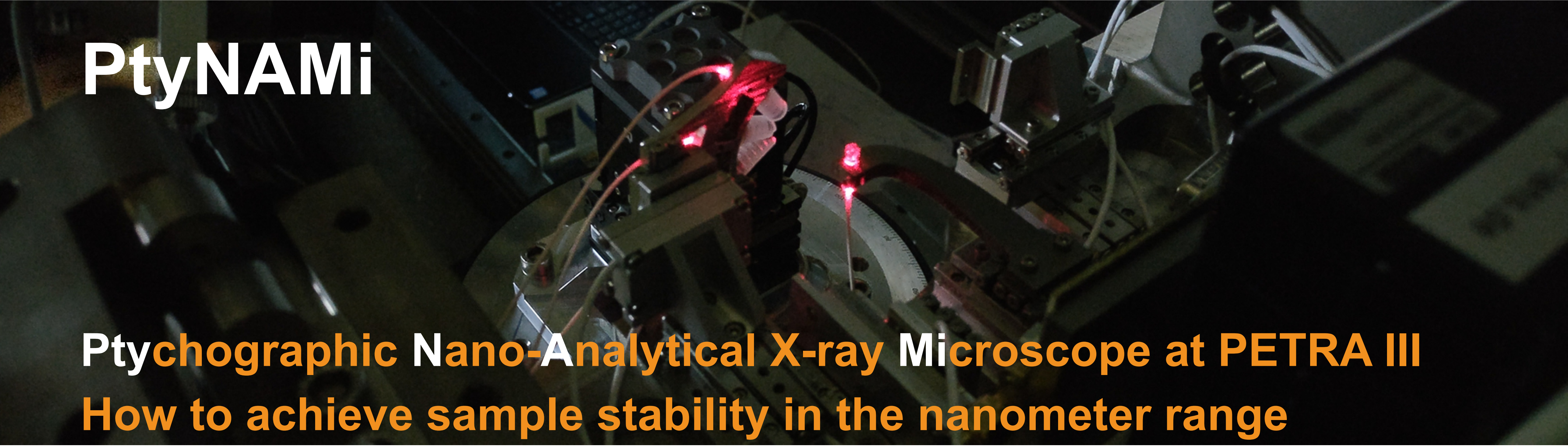


# PtyNAMi

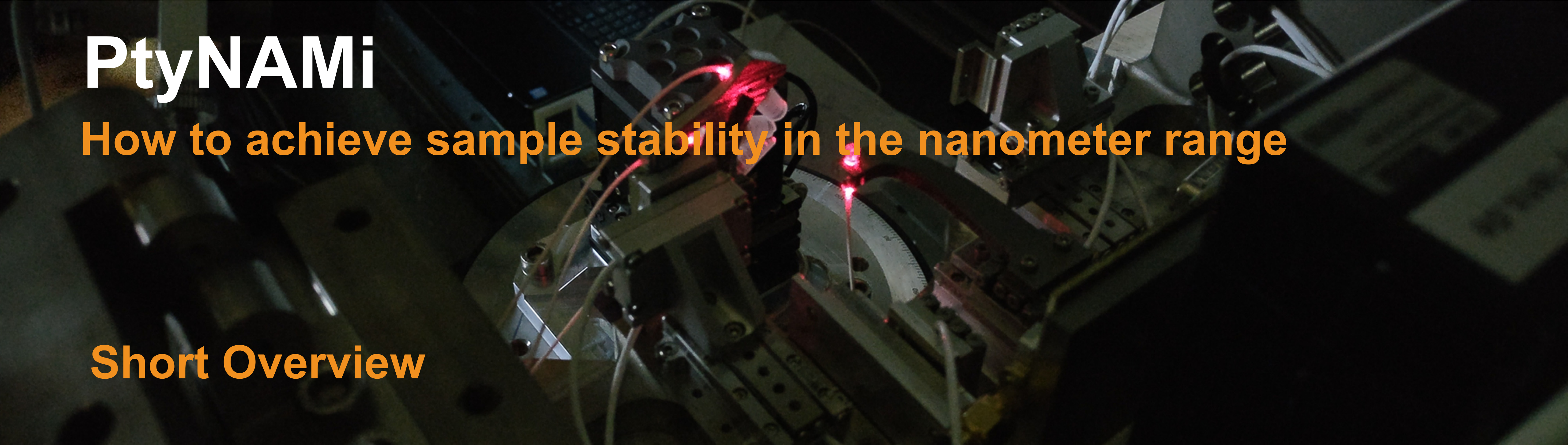
## Ptychographic Nano-Analytical X-ray Microscope at PETRA III
## How to achieve sample stability in the nanometer range


**Ralph Döhrmann**
Paris, 28 June 2018



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.



# PtyNAMi

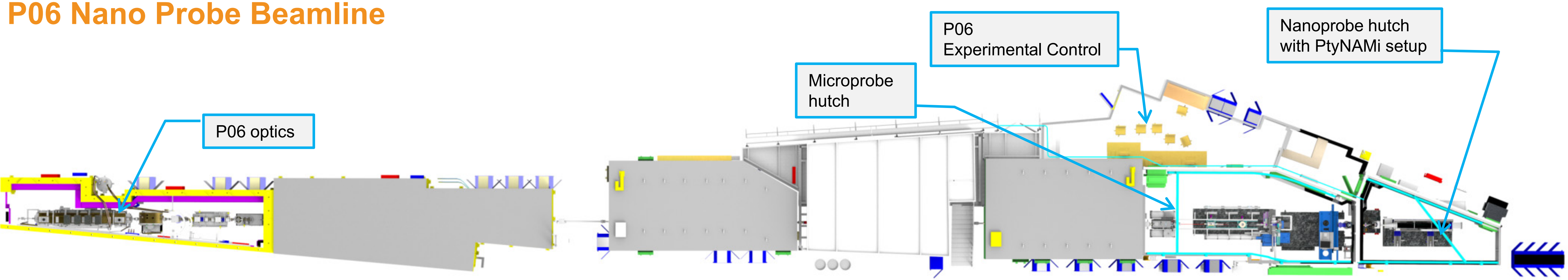
## How to achieve sample stability in the nanometer range

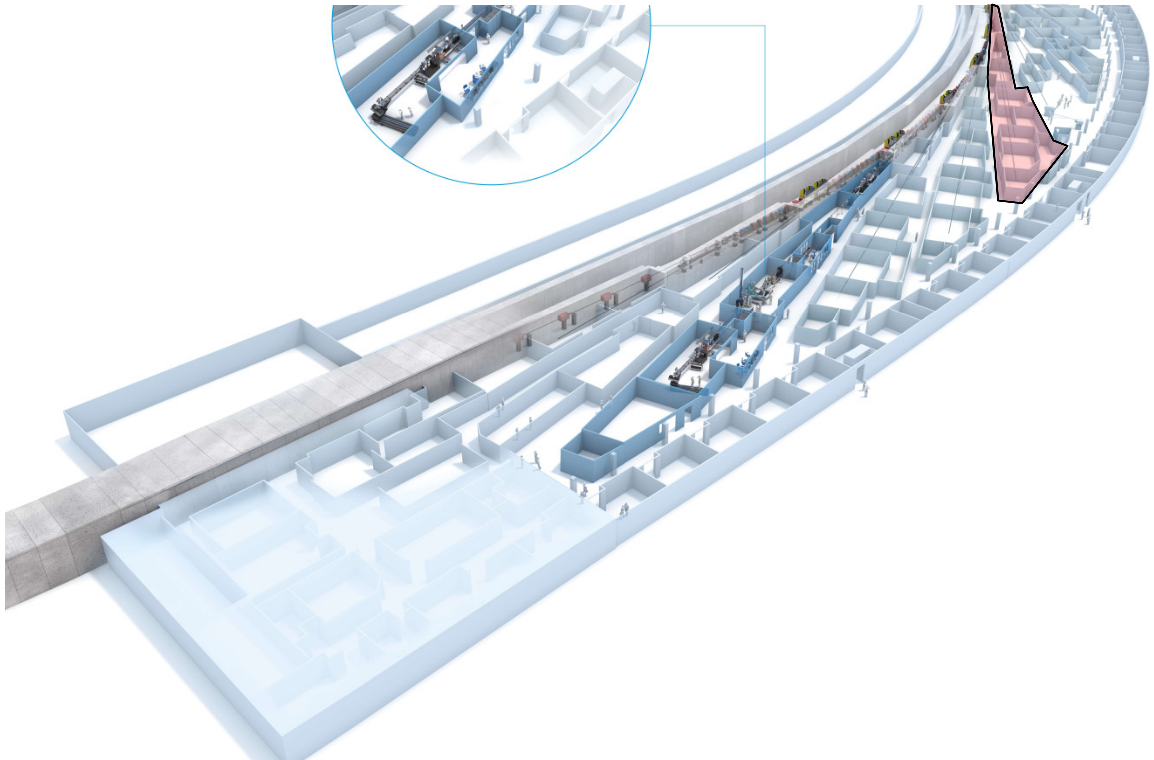
## Short Overview

- **Experimental methods**
- **Beamline layout**
- **Experimental setup**
- **Performed measurements**
- **Stability considerations**

# Beamline Layout

## P06 Nano Probe Beamline



### Hard X-ray
### Micro/Nano-Probe Beamline P06

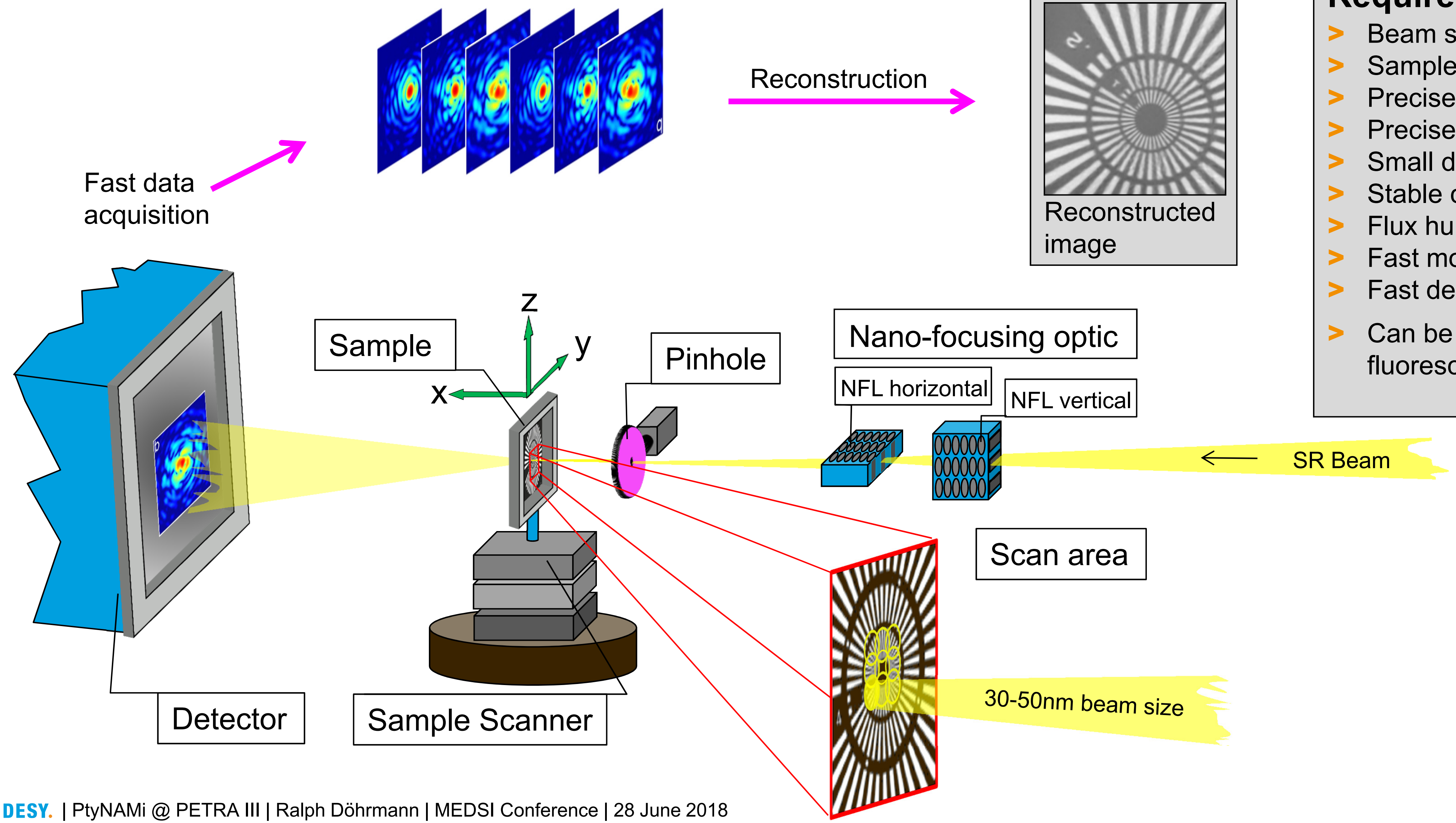
- energy range from 7 to 30 KeV
- Focus size: 30 - 80 nm

# Experimental methods

## Why do we need stable conditions for Ptychography

# Experimental methods

## Ptychography at the P06 Nanoprobe experiment

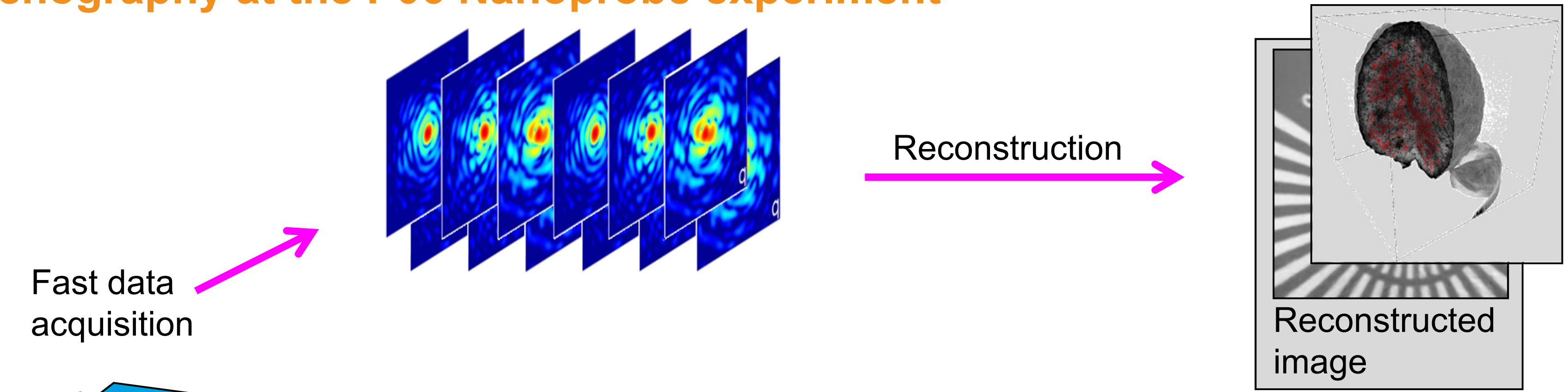


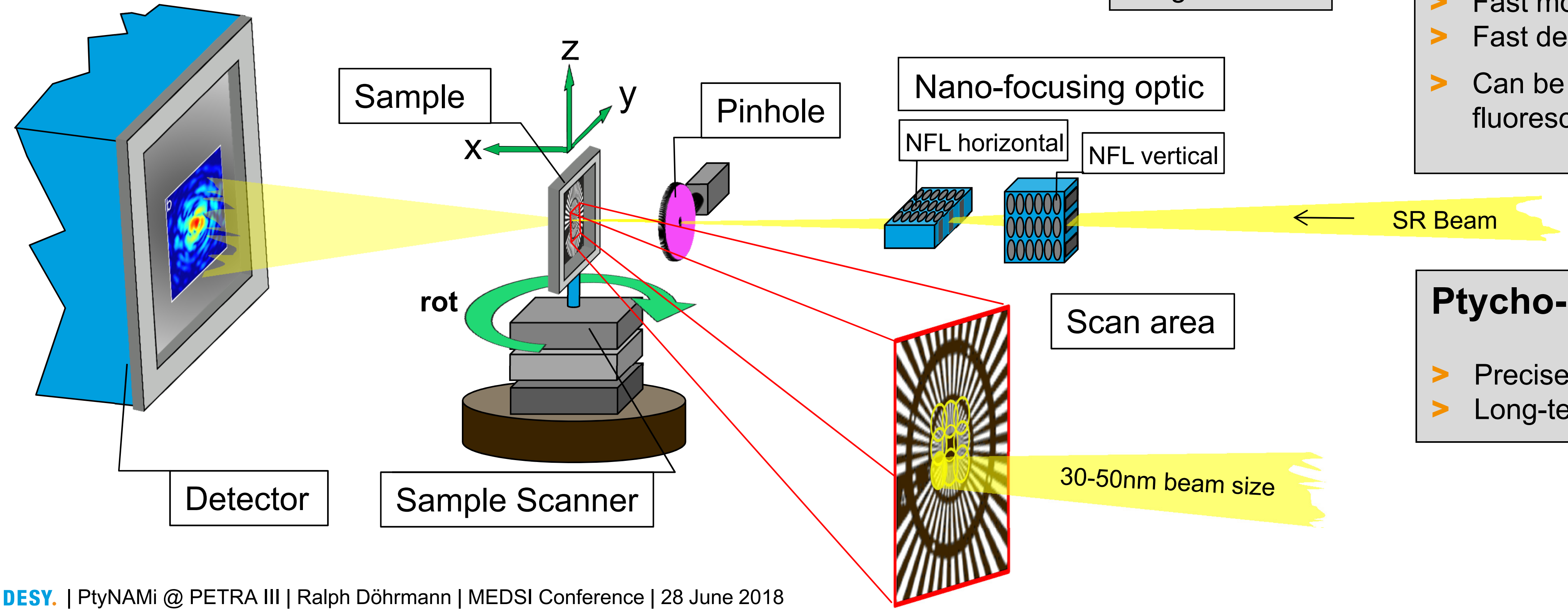

**Requirements**

- Beam size below 50nm
- Sample scans
- Precise movements
- Precise position information
- Small distances (2-30mm)
- Stable conditions
- Flux hungry
- Fast movements
- Fast detectors
- Can be combined with fluorescence measurements

# Experimental methods

## Ptychography at the P06 Nanoprobe experiment

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### Ptycho- tomography

- Precise rotation
- Long-term stability

# PtyNAMi

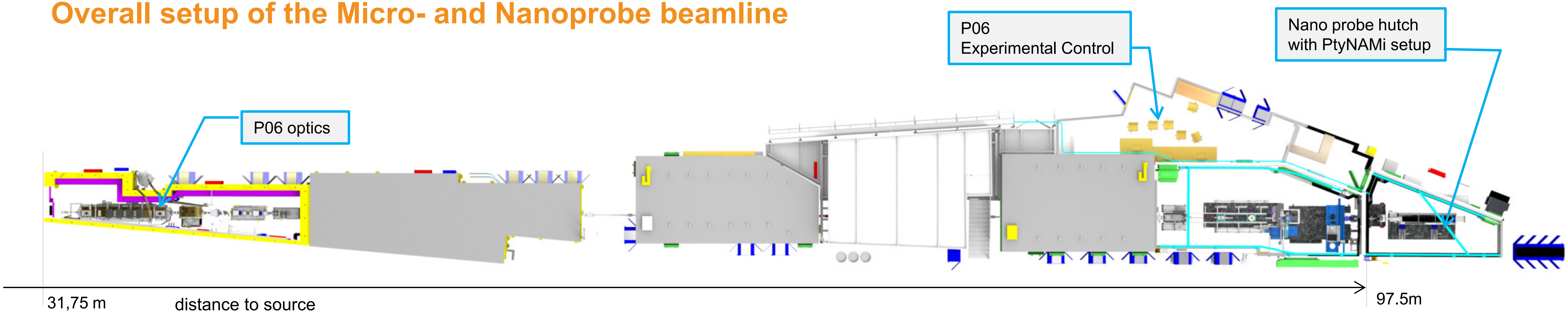
How to achieve sample stability in the nanometer range

# Beamline Layout

## For beamline P06 and nanoprobe endstation

# Beamline Layout

## Overall setup of the Micro- and Nanoprobe beamline



# Beamline Layout

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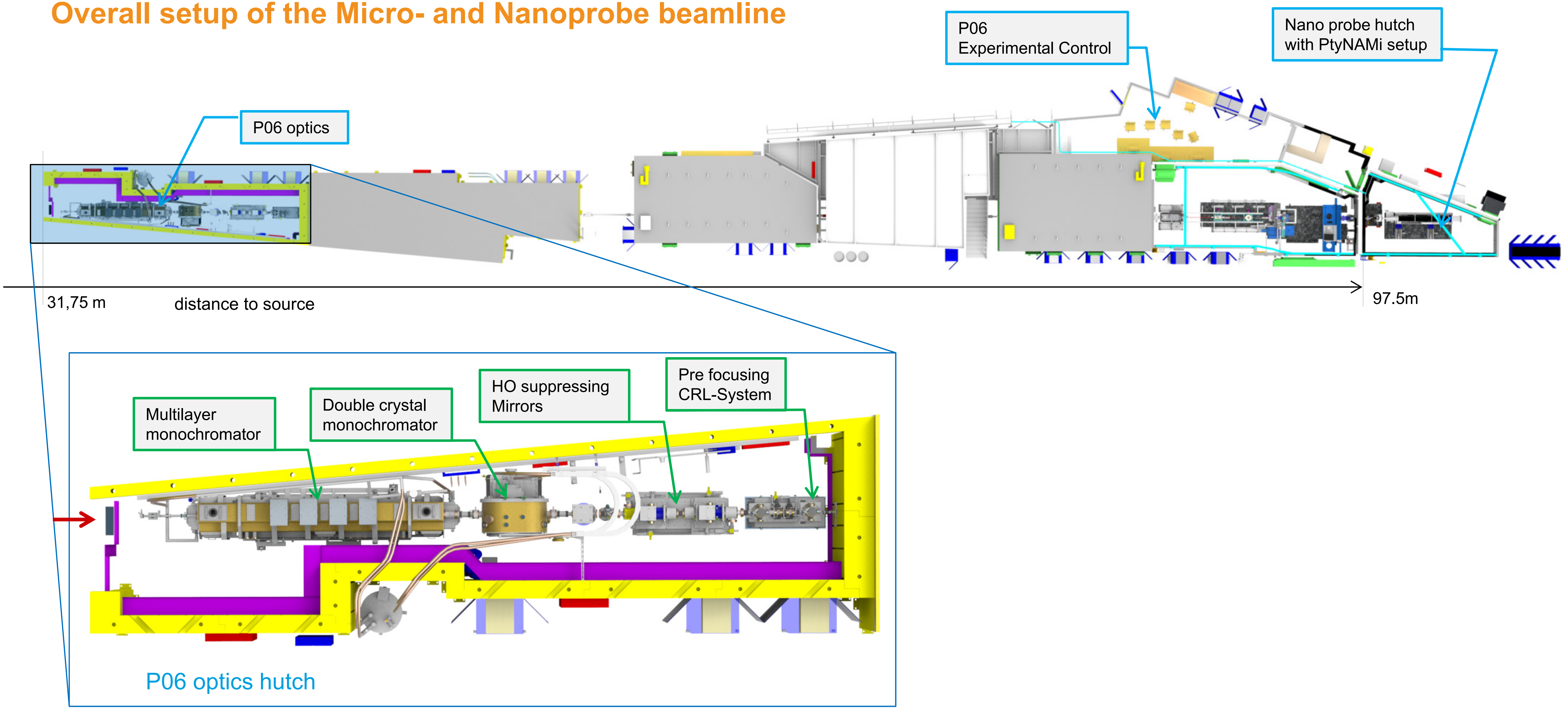

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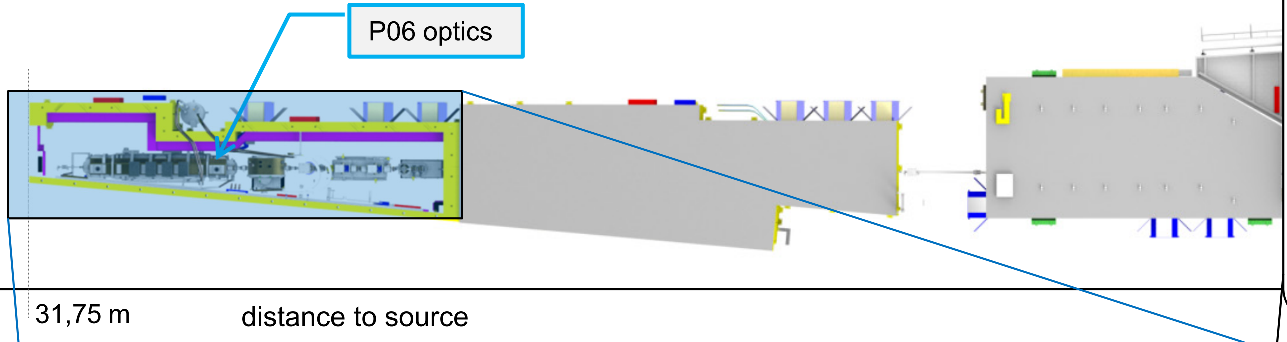
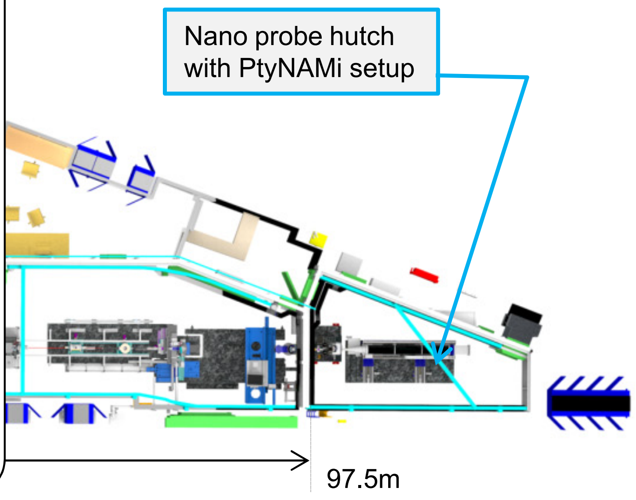
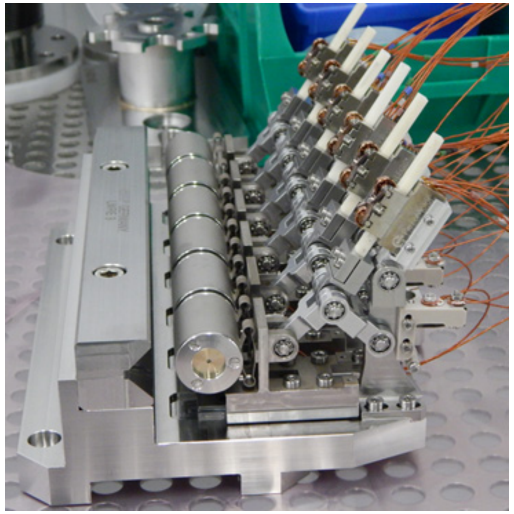
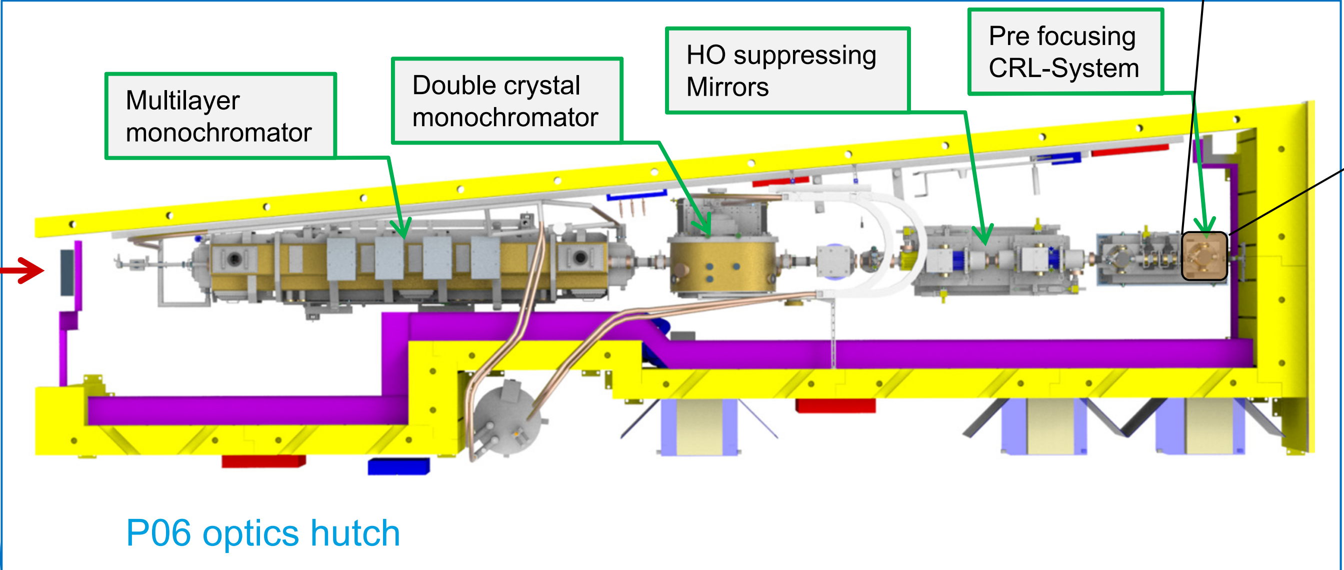


Vacuum chamber with CRL-changer system for pre-focusing




### Micro-focusing CRL-lens system:

- Binary stack arrangement
- Adaptable to energy
- Pre focus size at Nano optics (100-200 µm)
- Increase intensity or coherence at sample

# Beamline Layout

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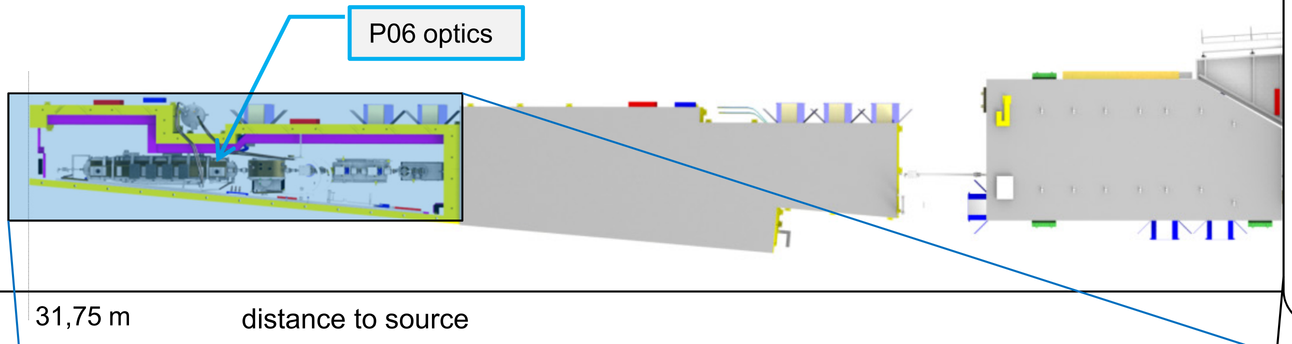


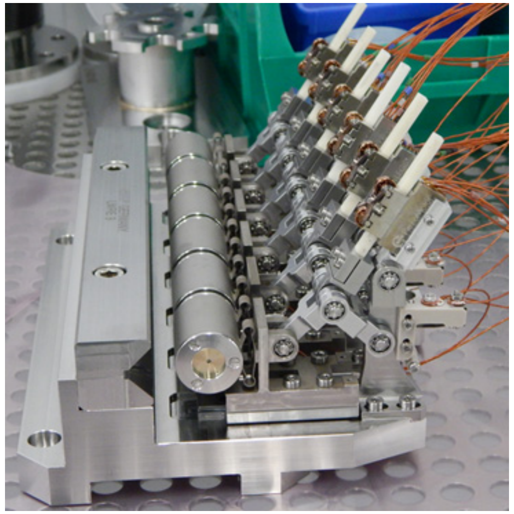

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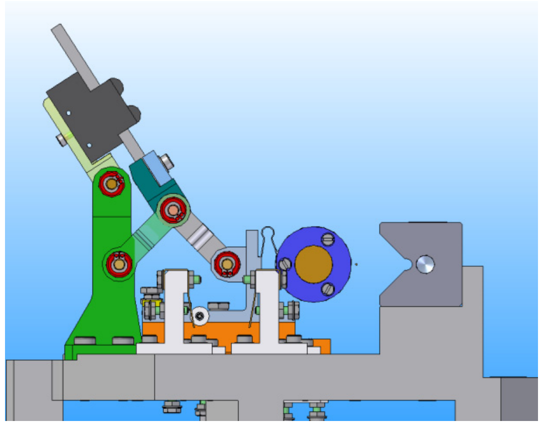

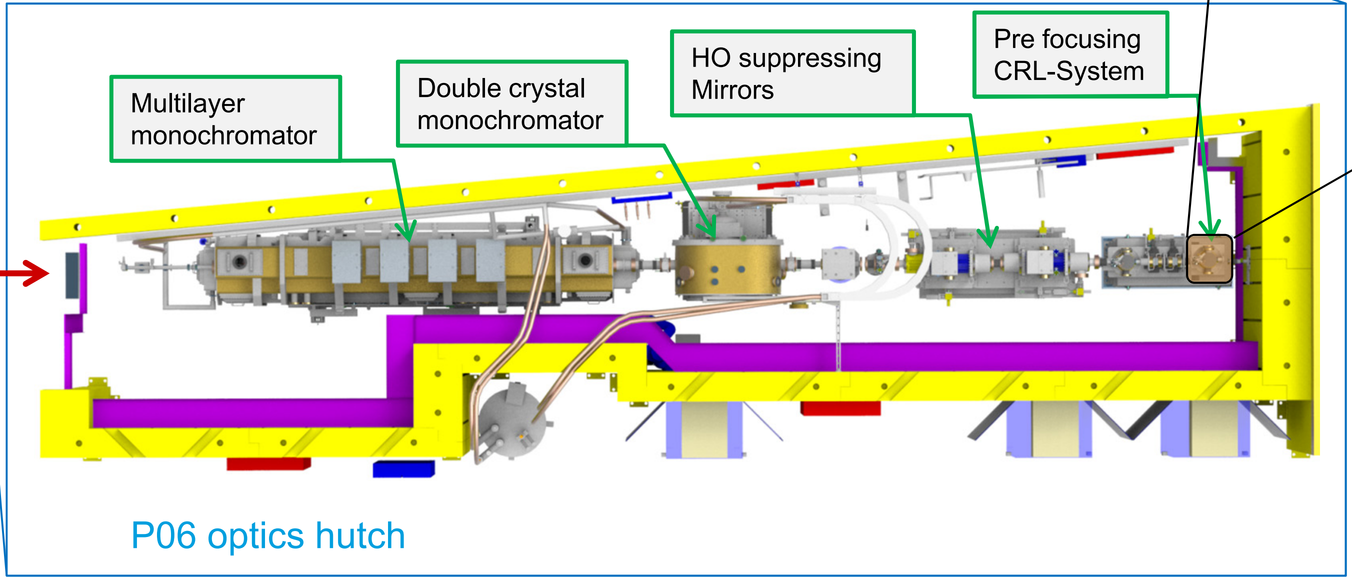


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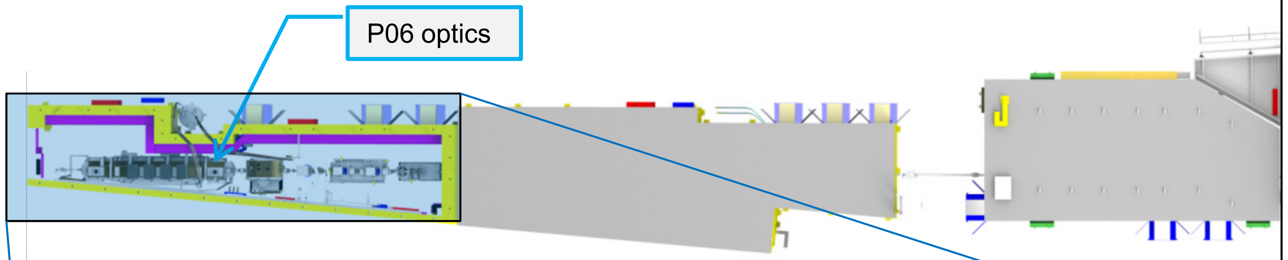
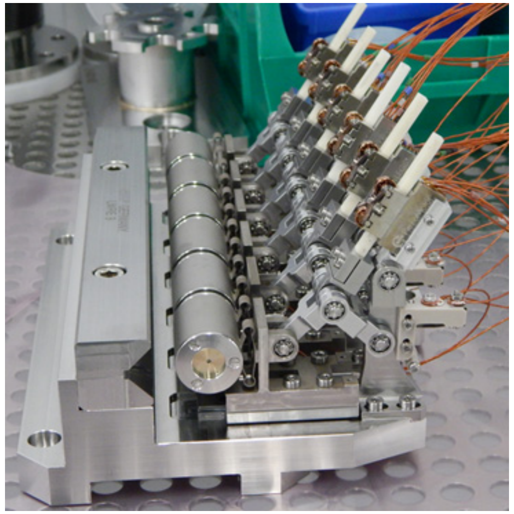



31,75 m distance to source



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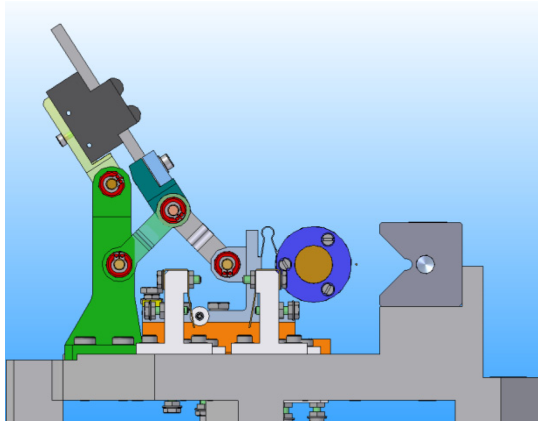
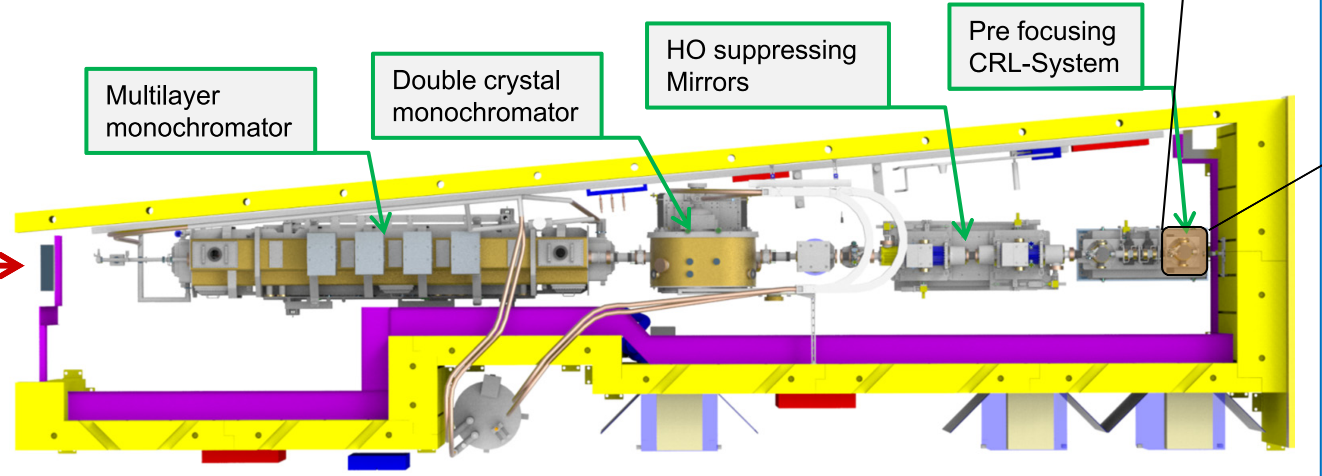


Force-amplification by toggle principle




P06 optics hutch

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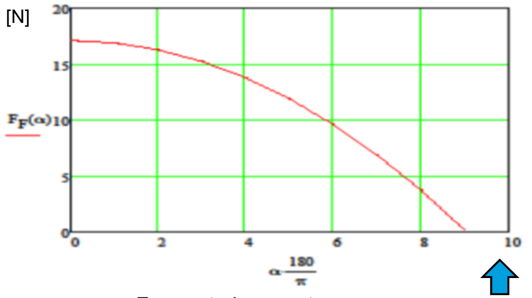
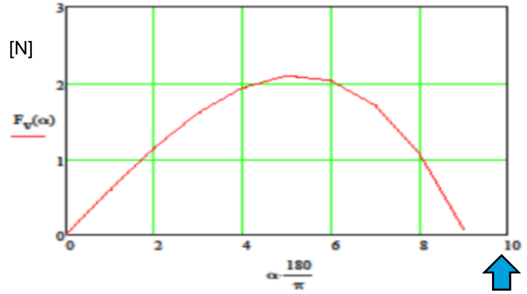



Force at piezo motor



# Beamline Layout

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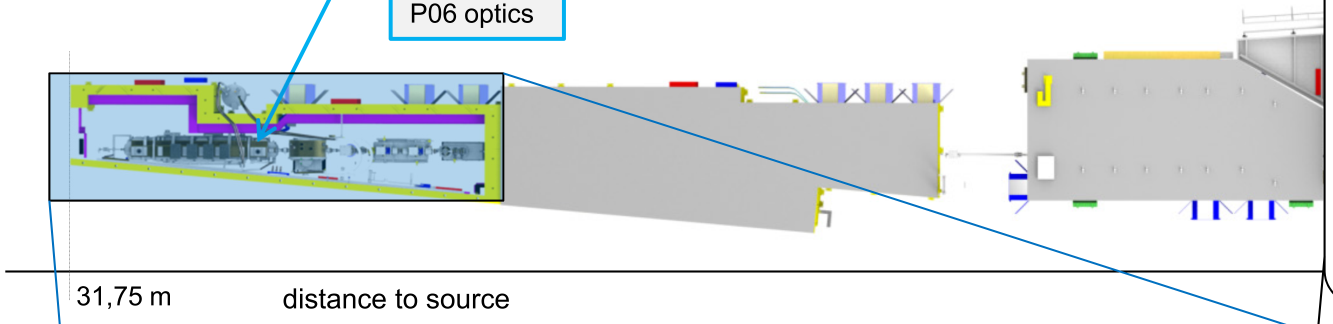


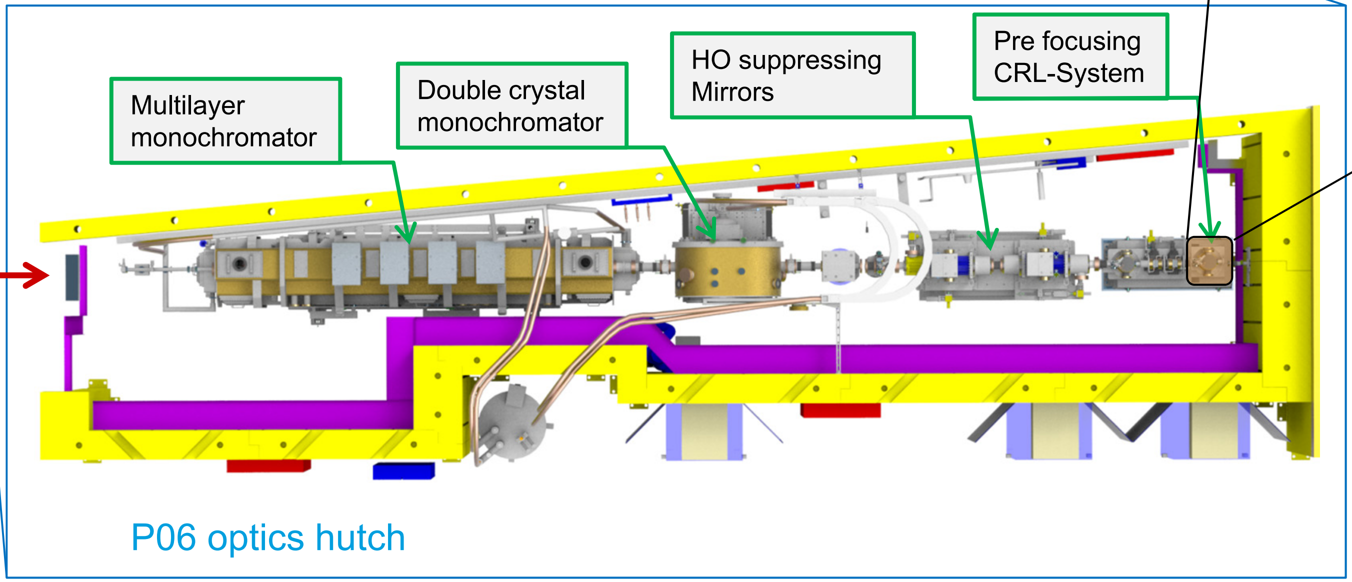


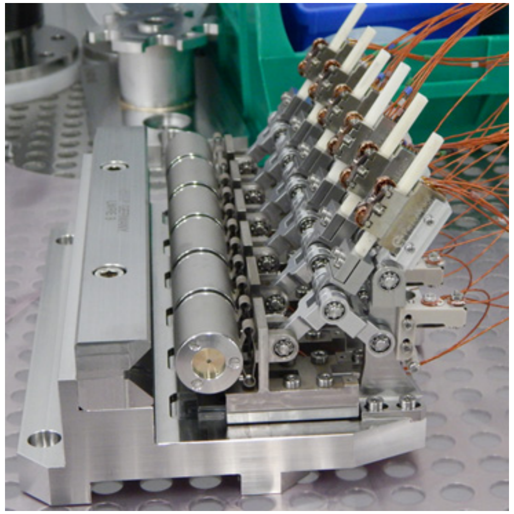

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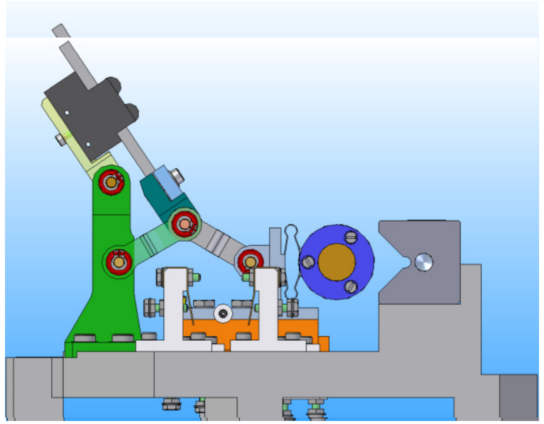

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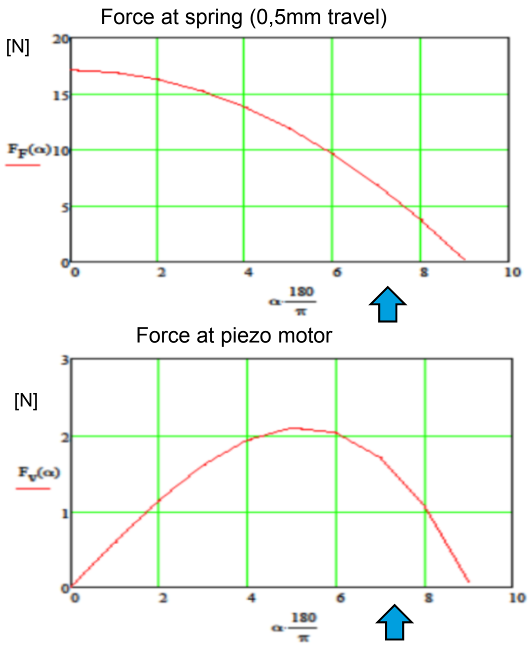

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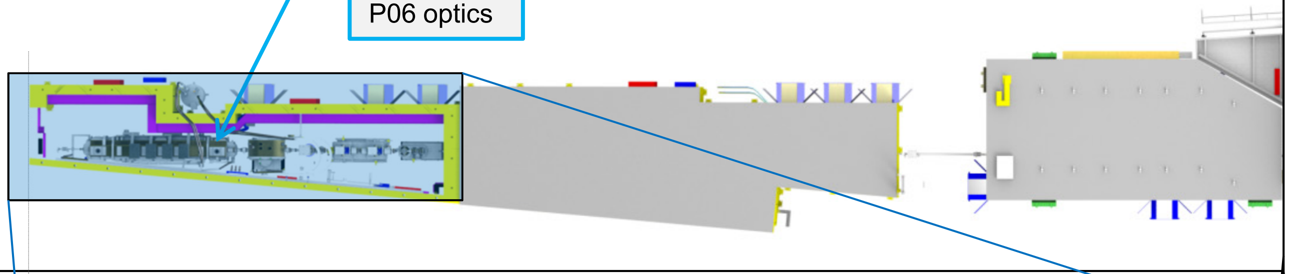


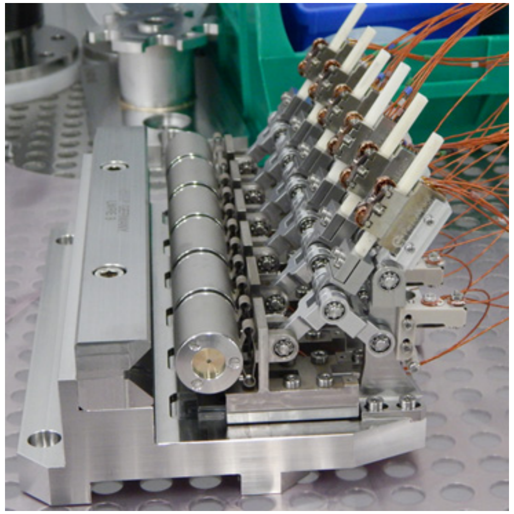

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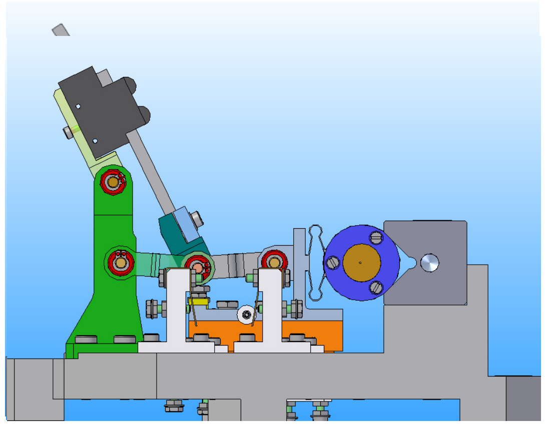

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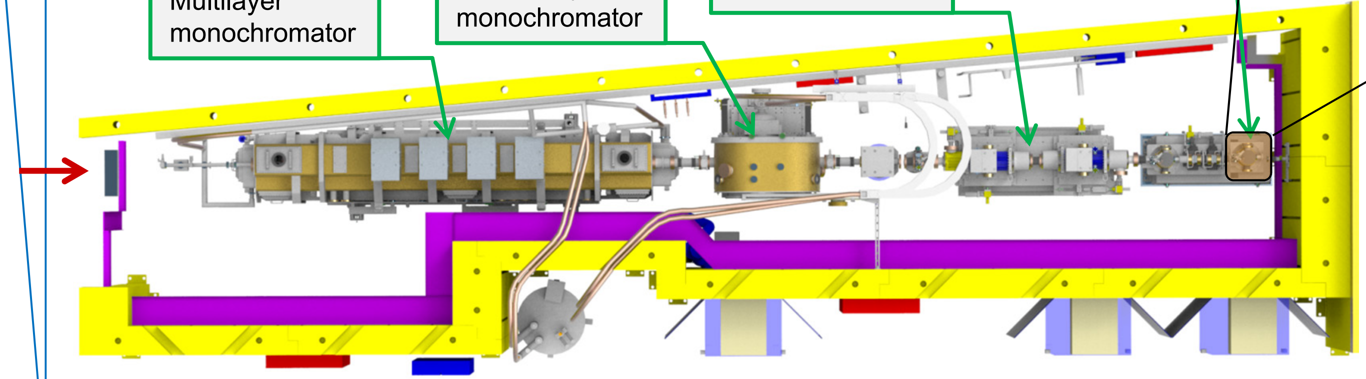


P06 optics hutch

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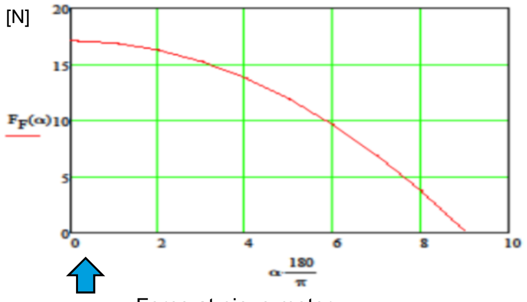


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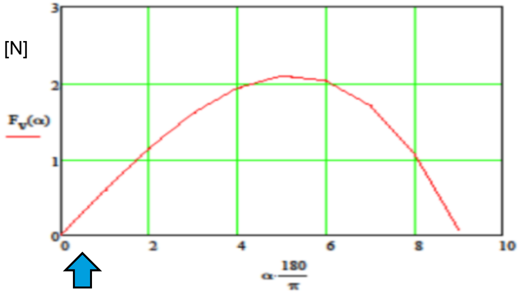

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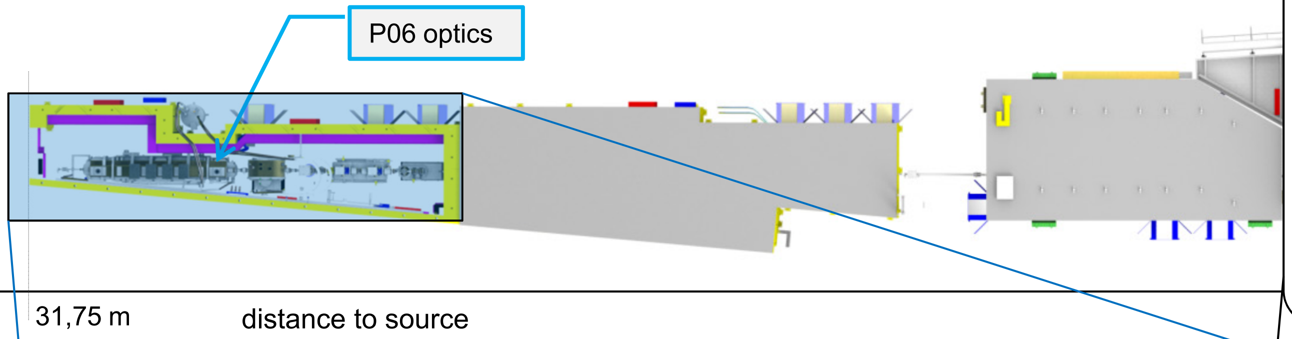


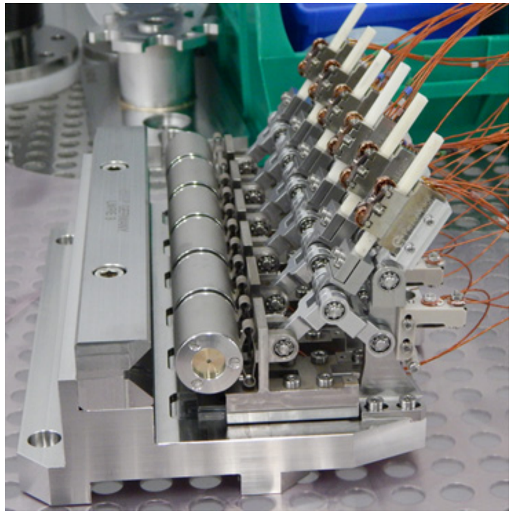

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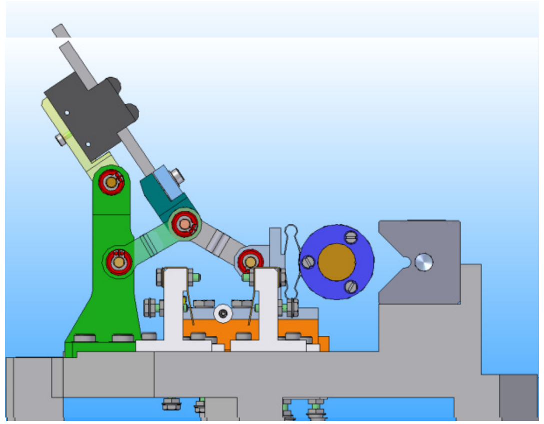

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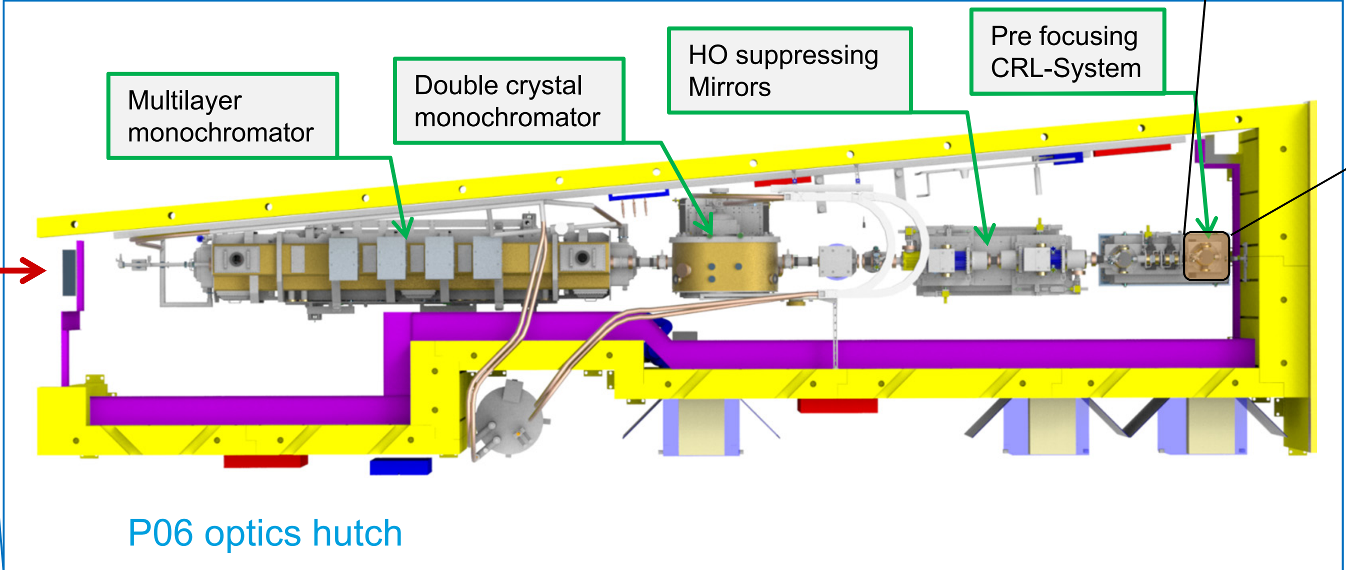


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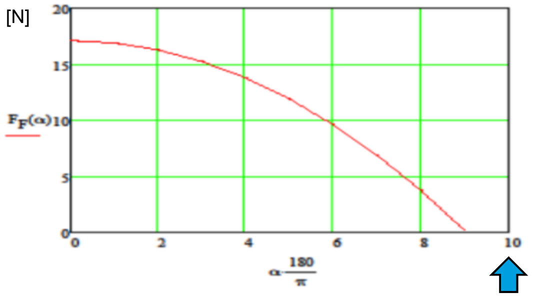


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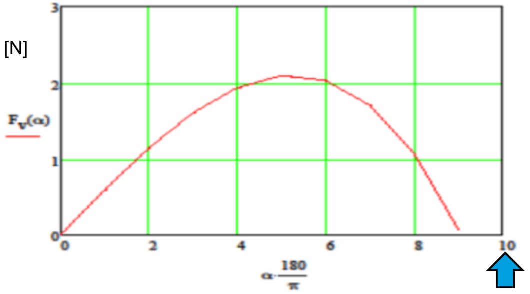

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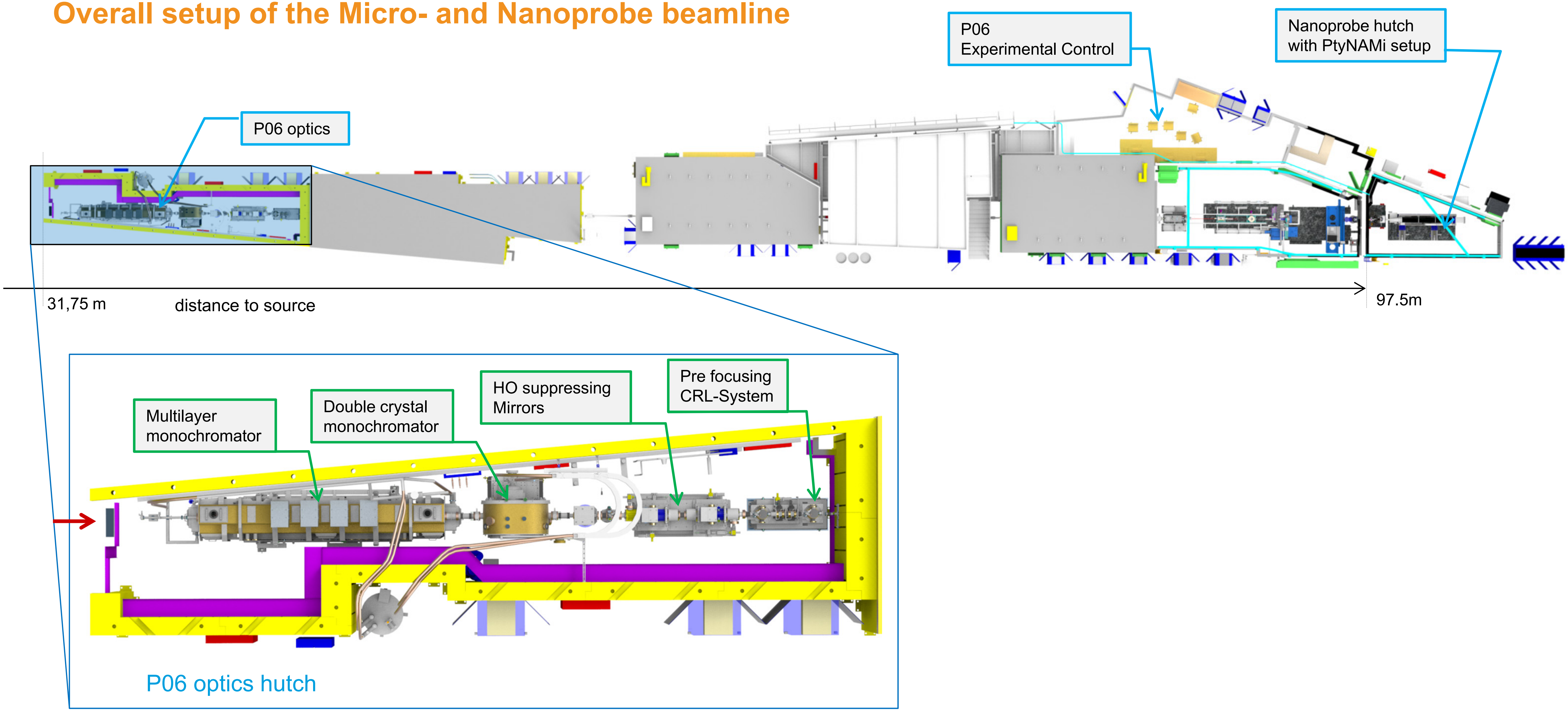

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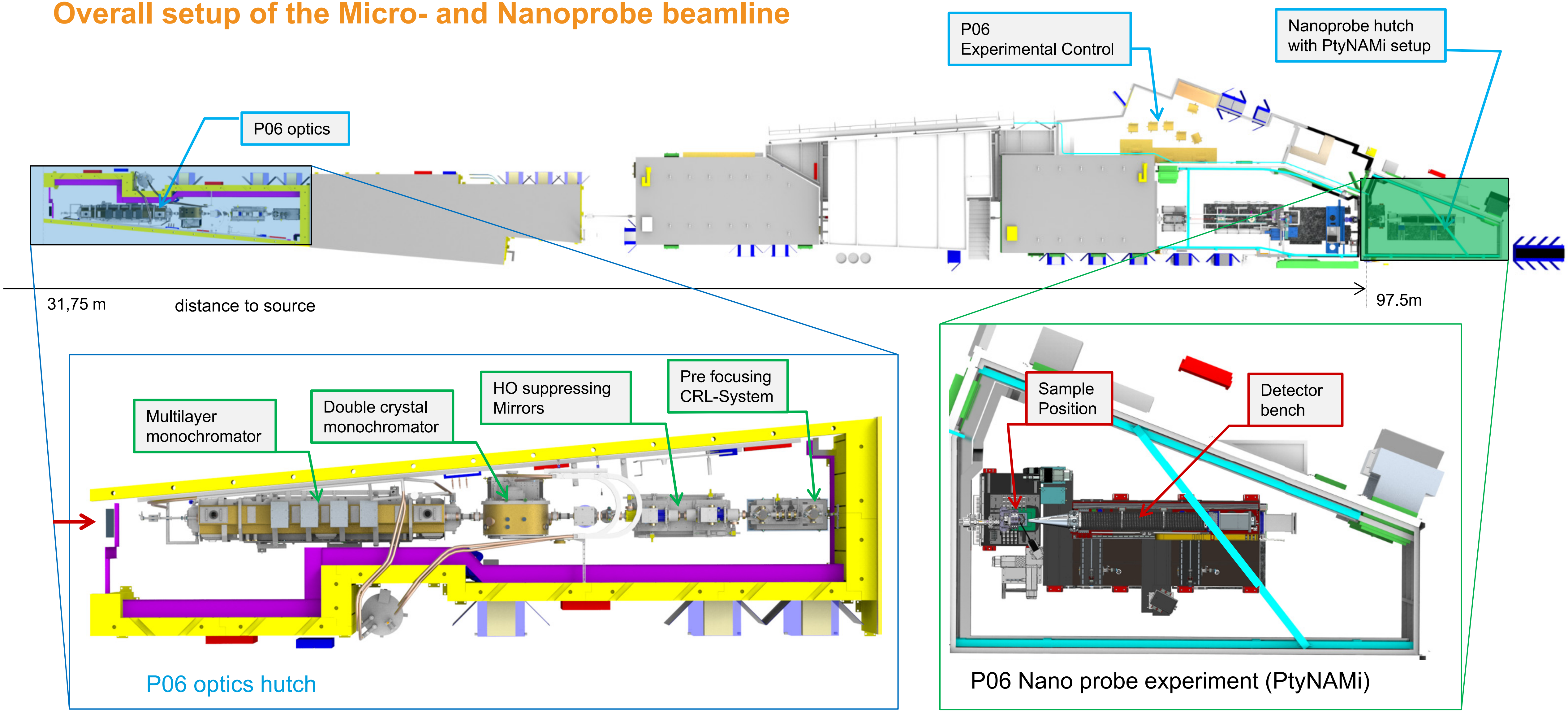

# Experimental Setup

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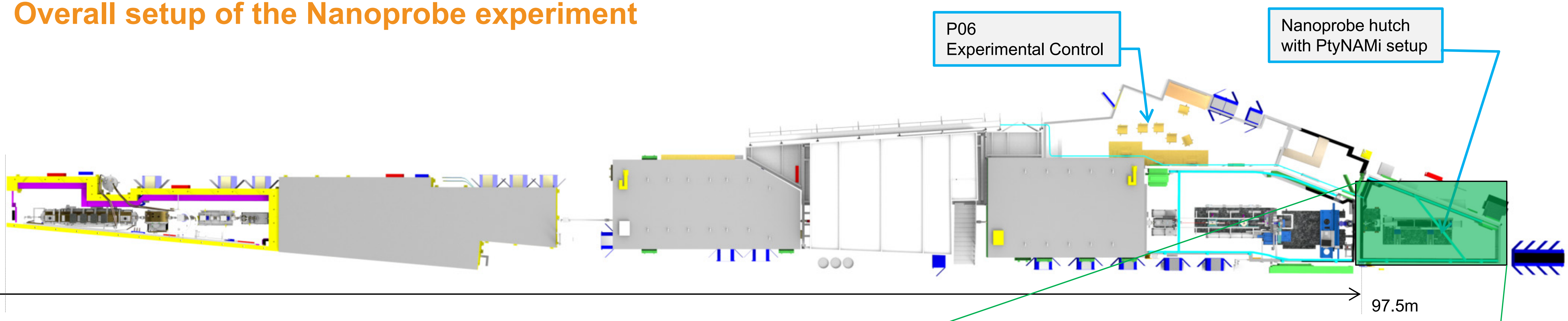
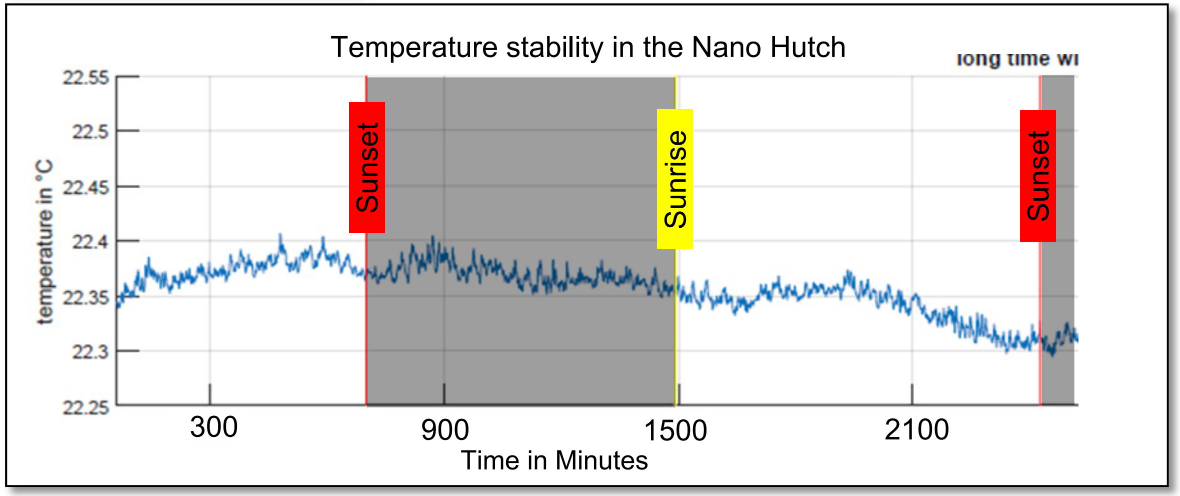
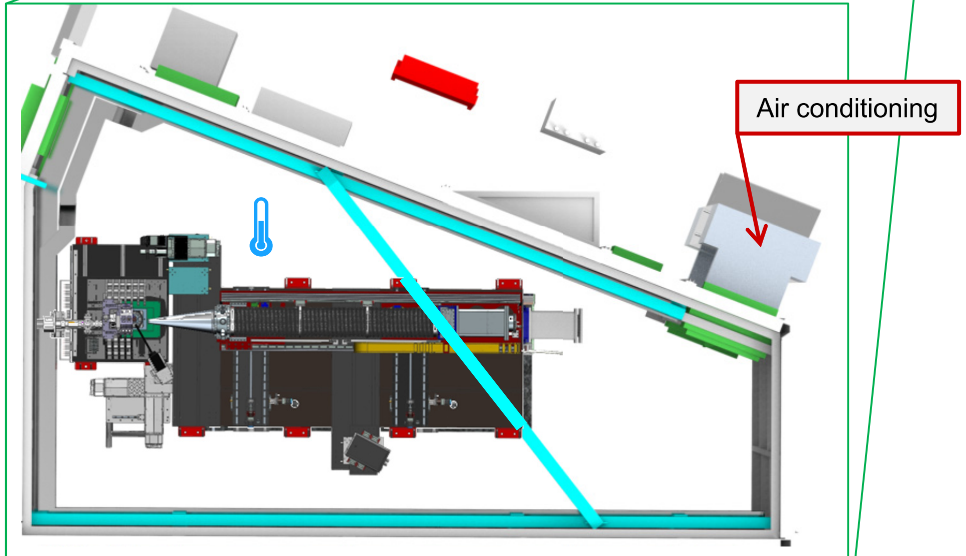



Short term 1-2h ±0.02K
Long term 1-2d ±0.05K




P06 Nano probe experiment (PtyNAMi)

# Experimental Setup

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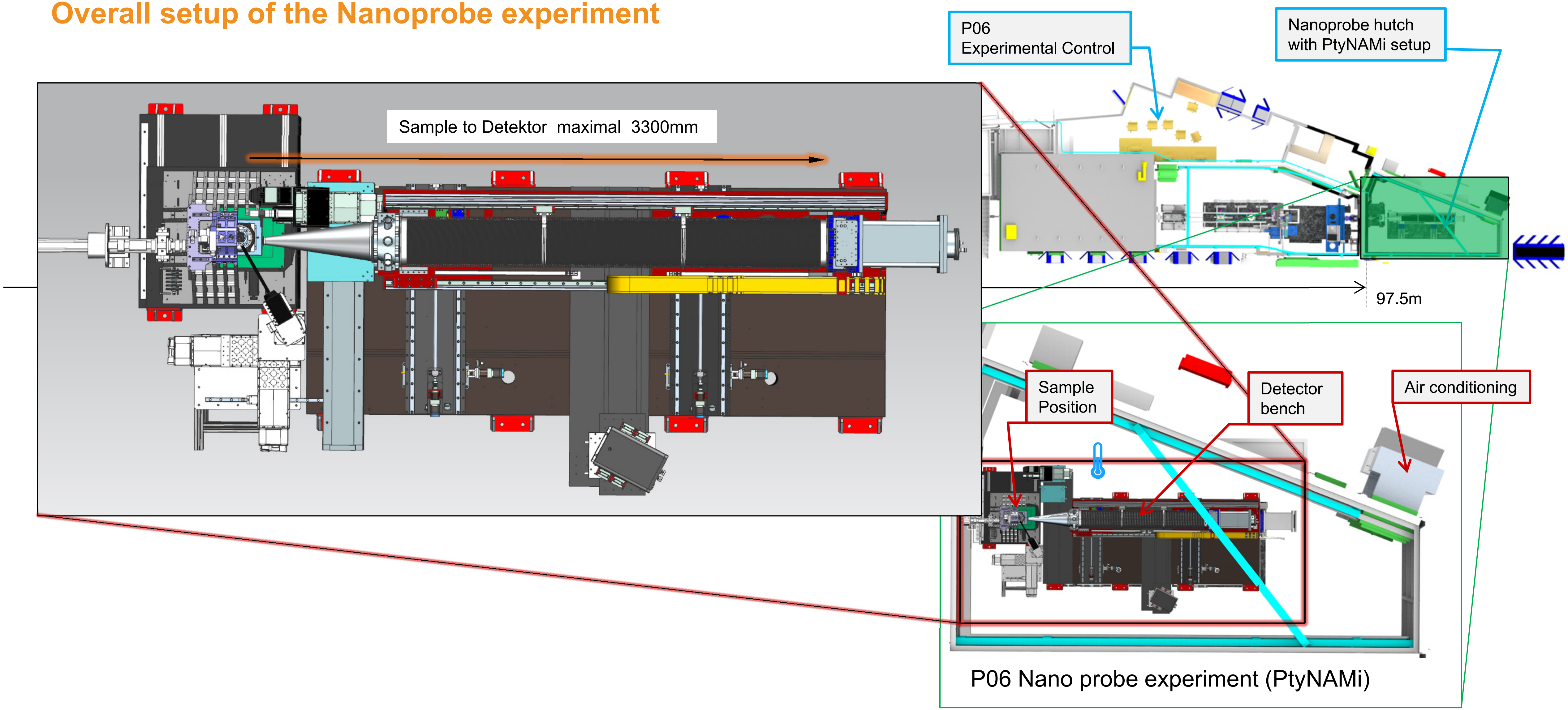

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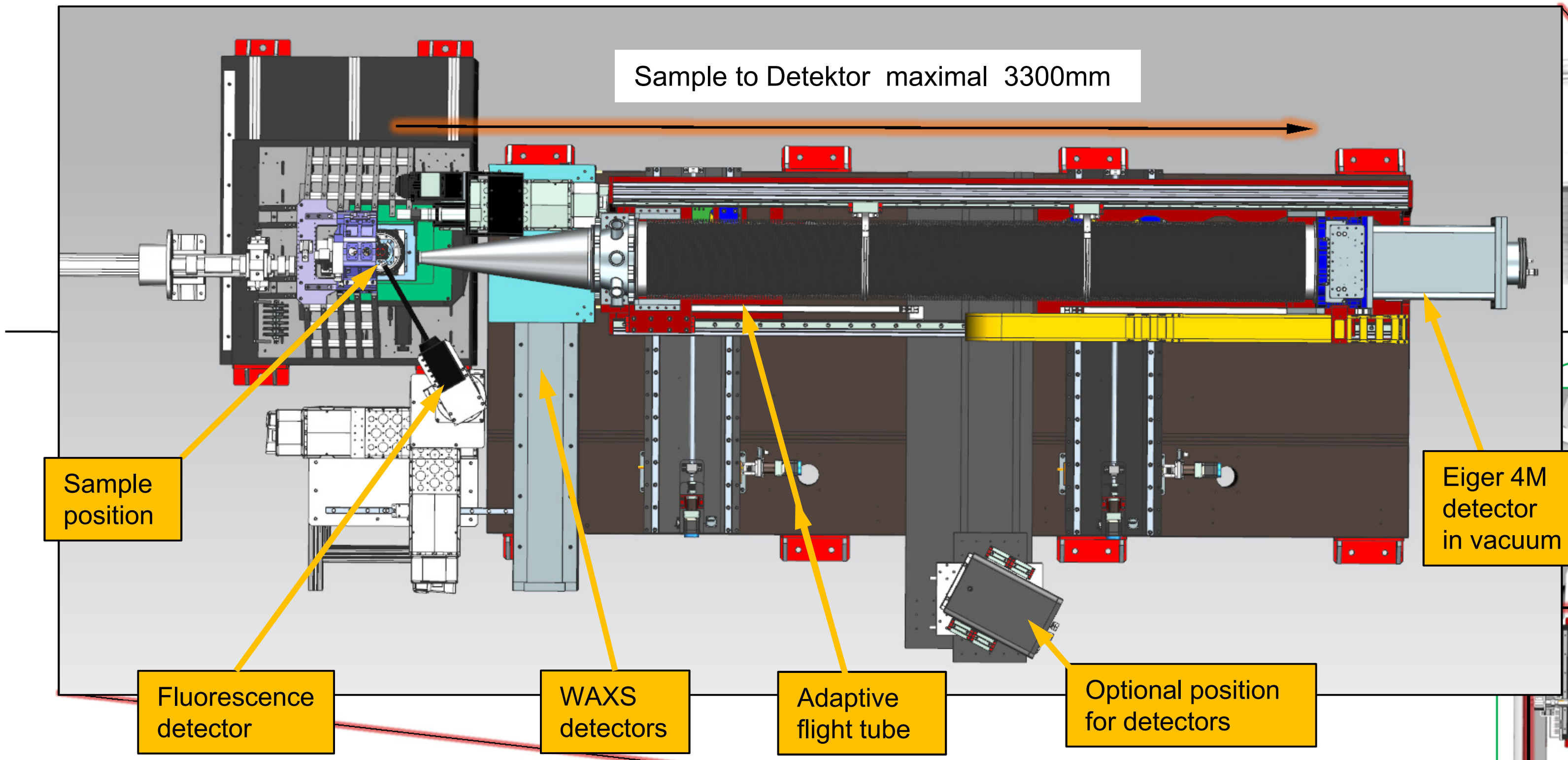
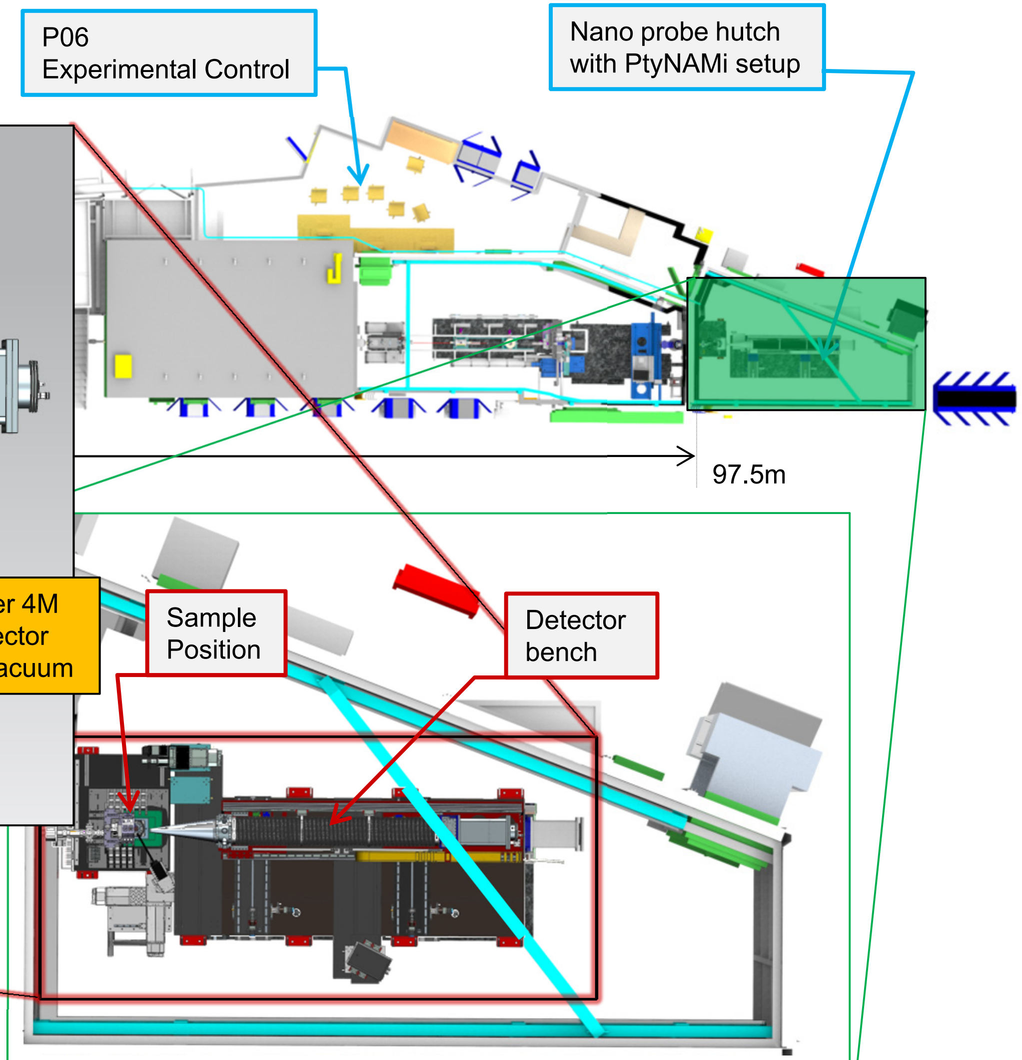


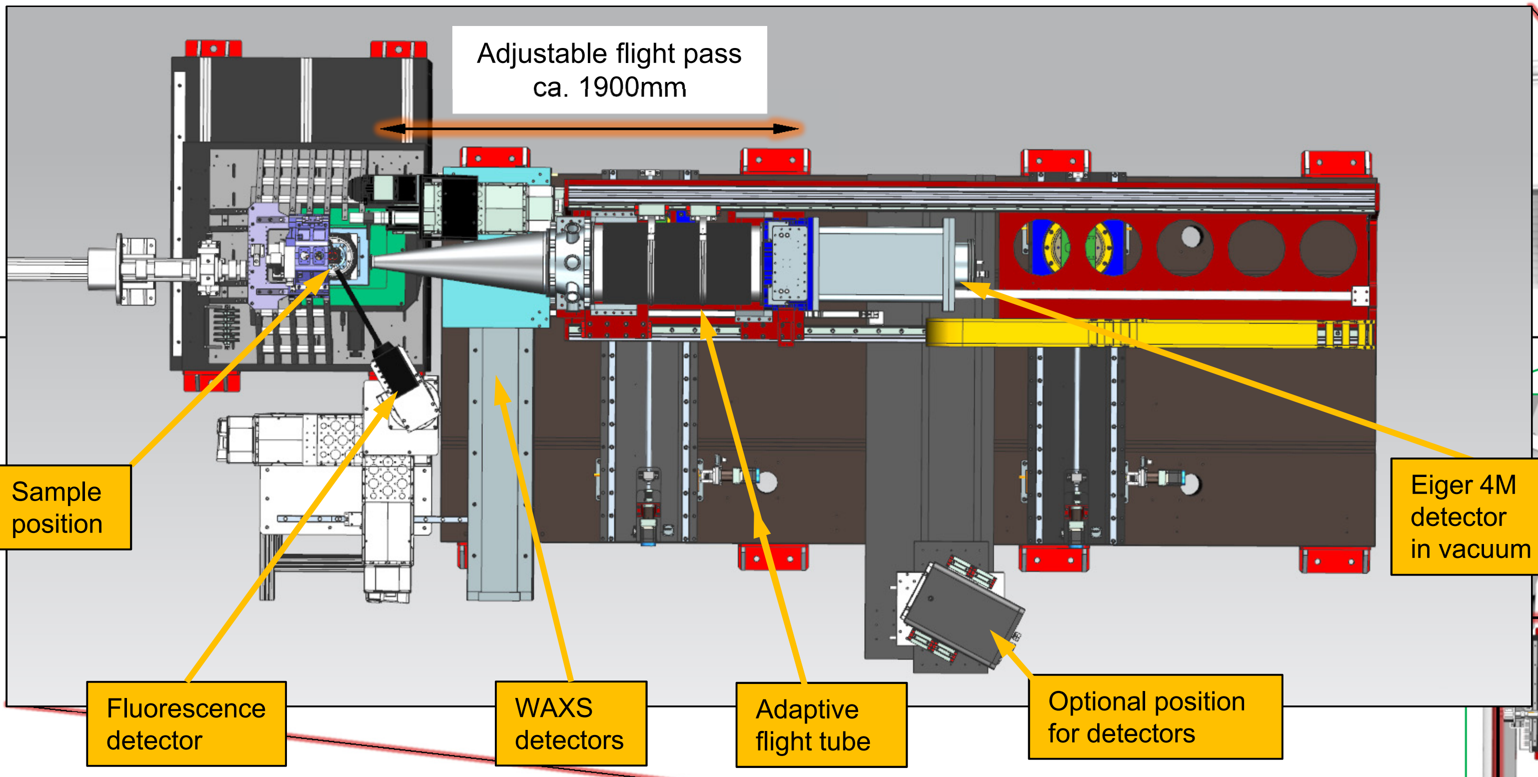



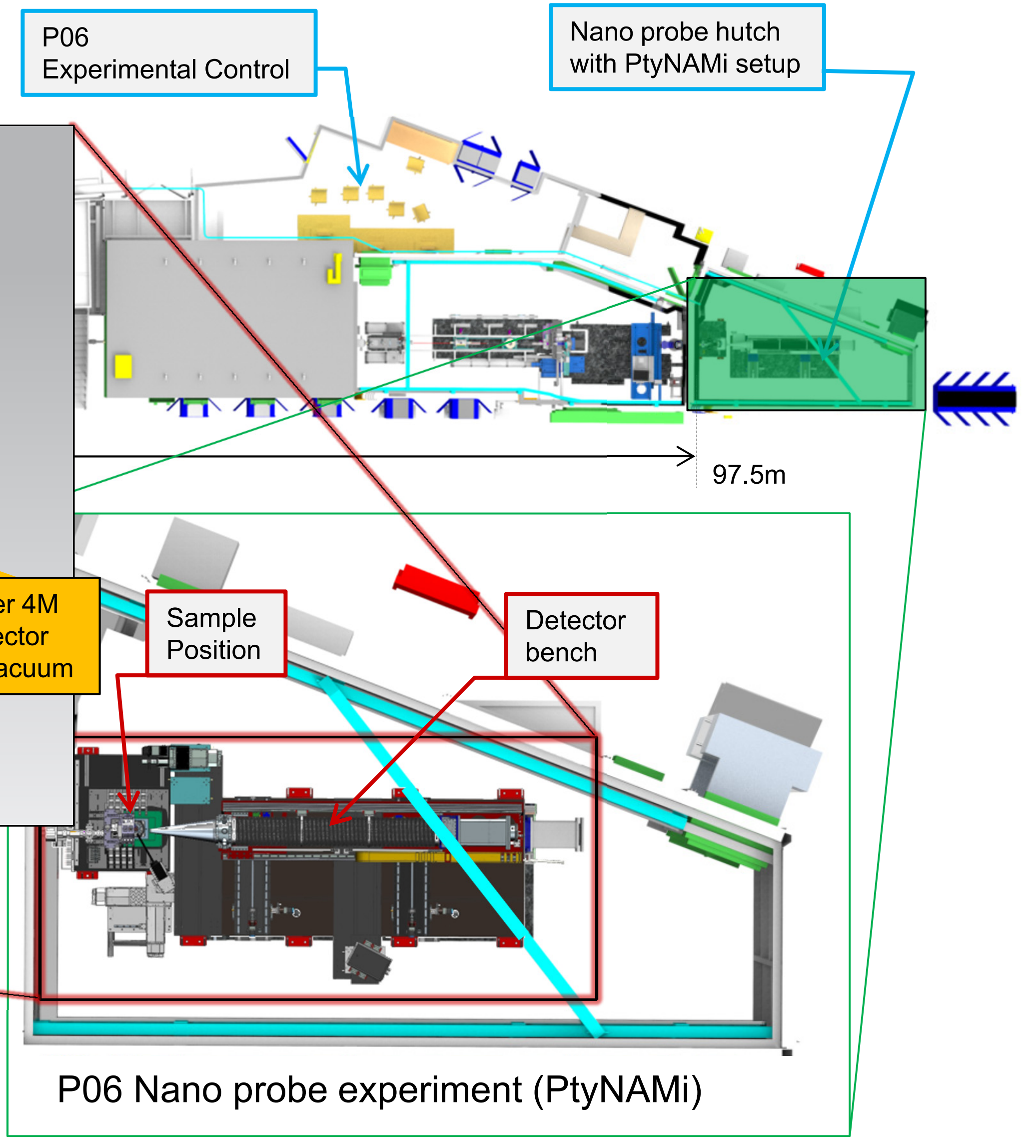

P06 Nano probe experiment (PtyNAMi)

Functionality of the detector bench

# Experimental Setup

## Overall setup of the Nanoprobe experiment

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Functionality of the detector bench

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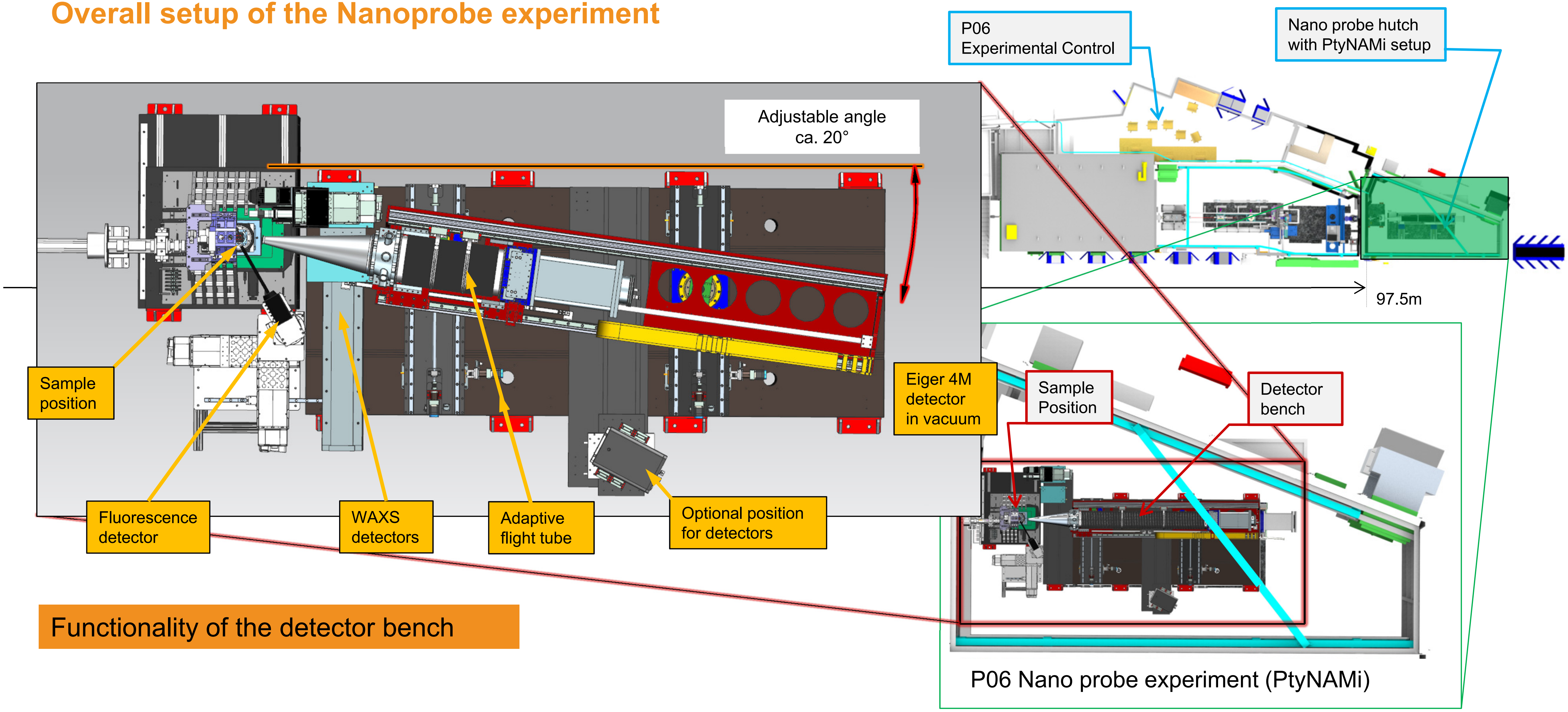


Functionality of the detector bench

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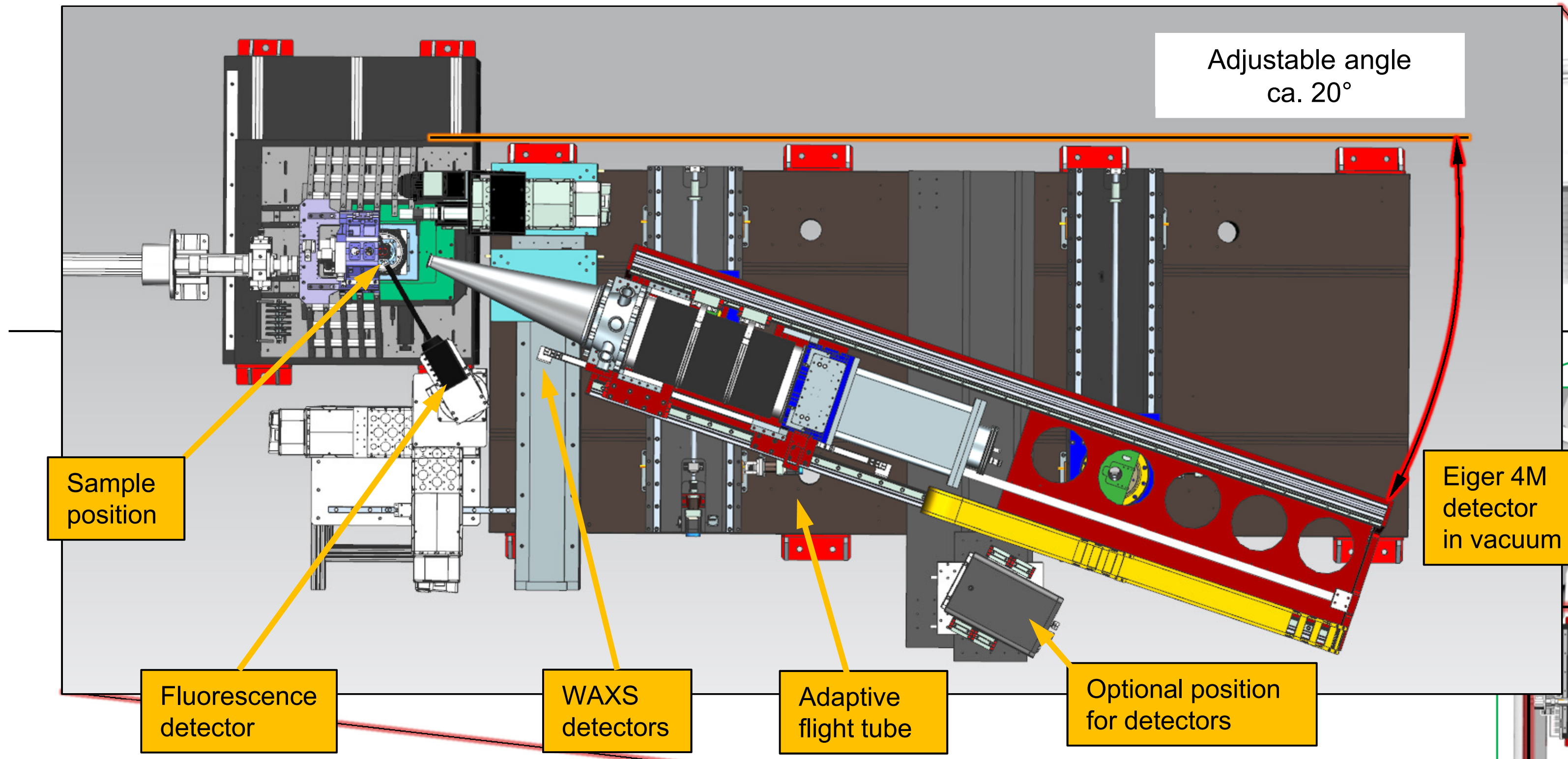


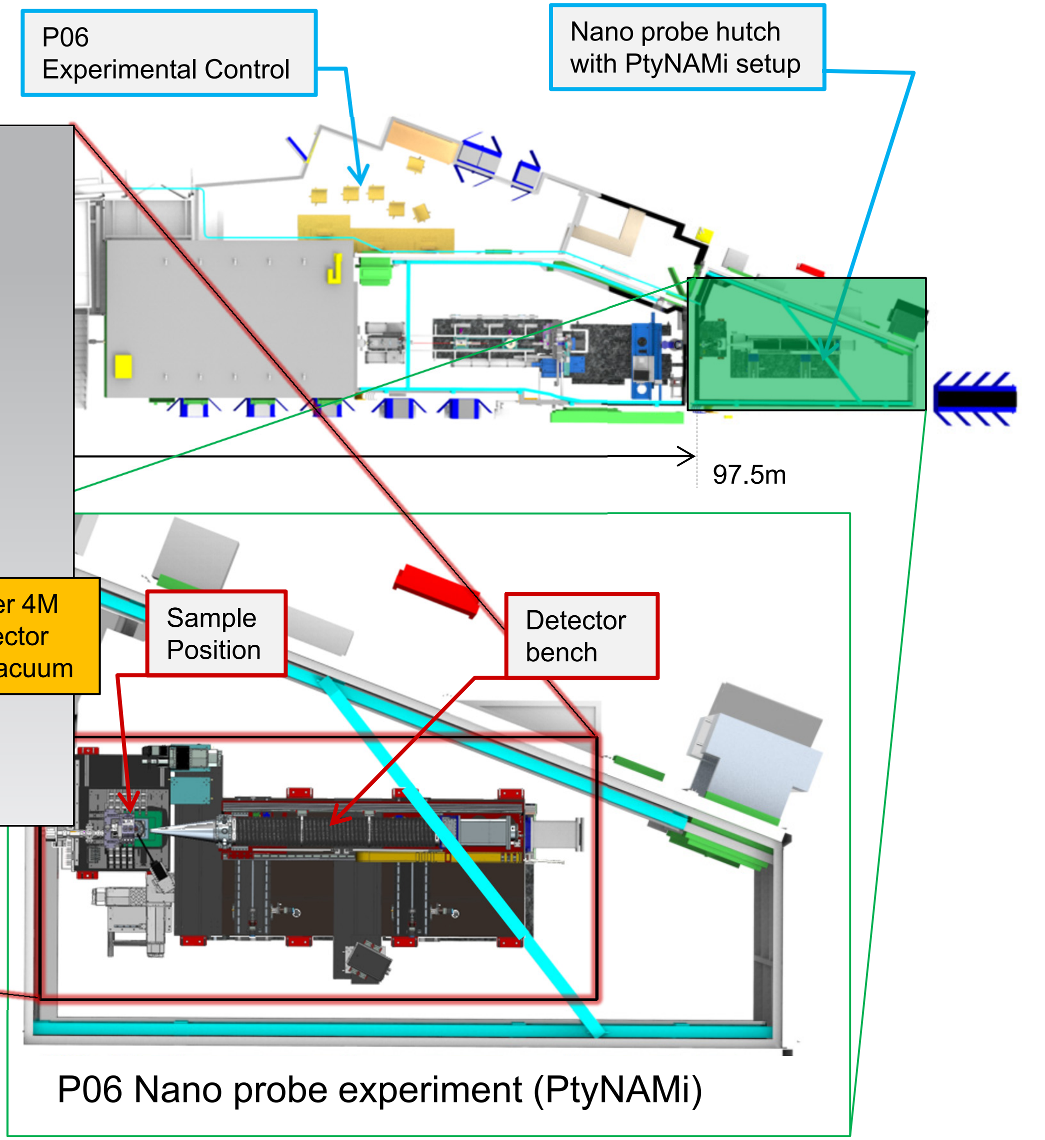


Functionality of the detector bench

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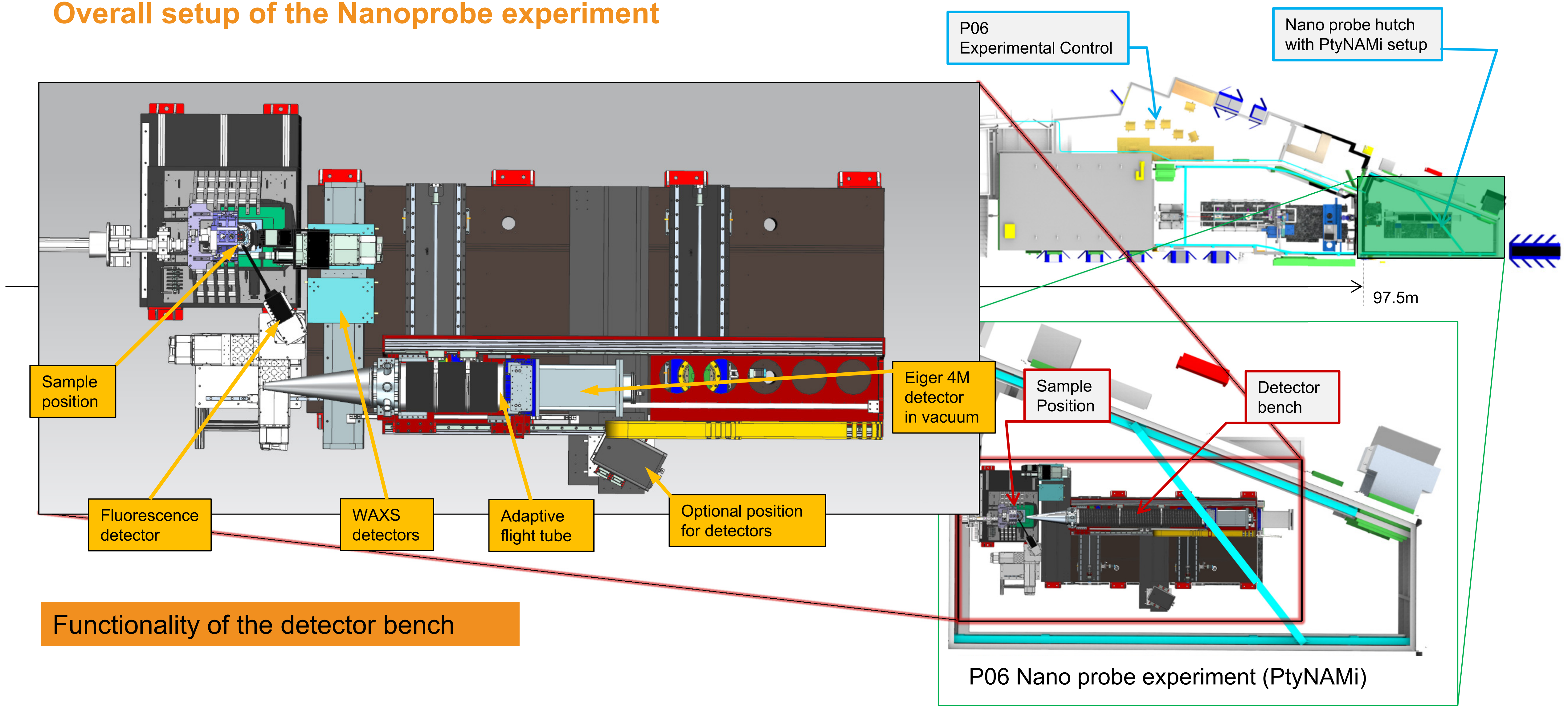
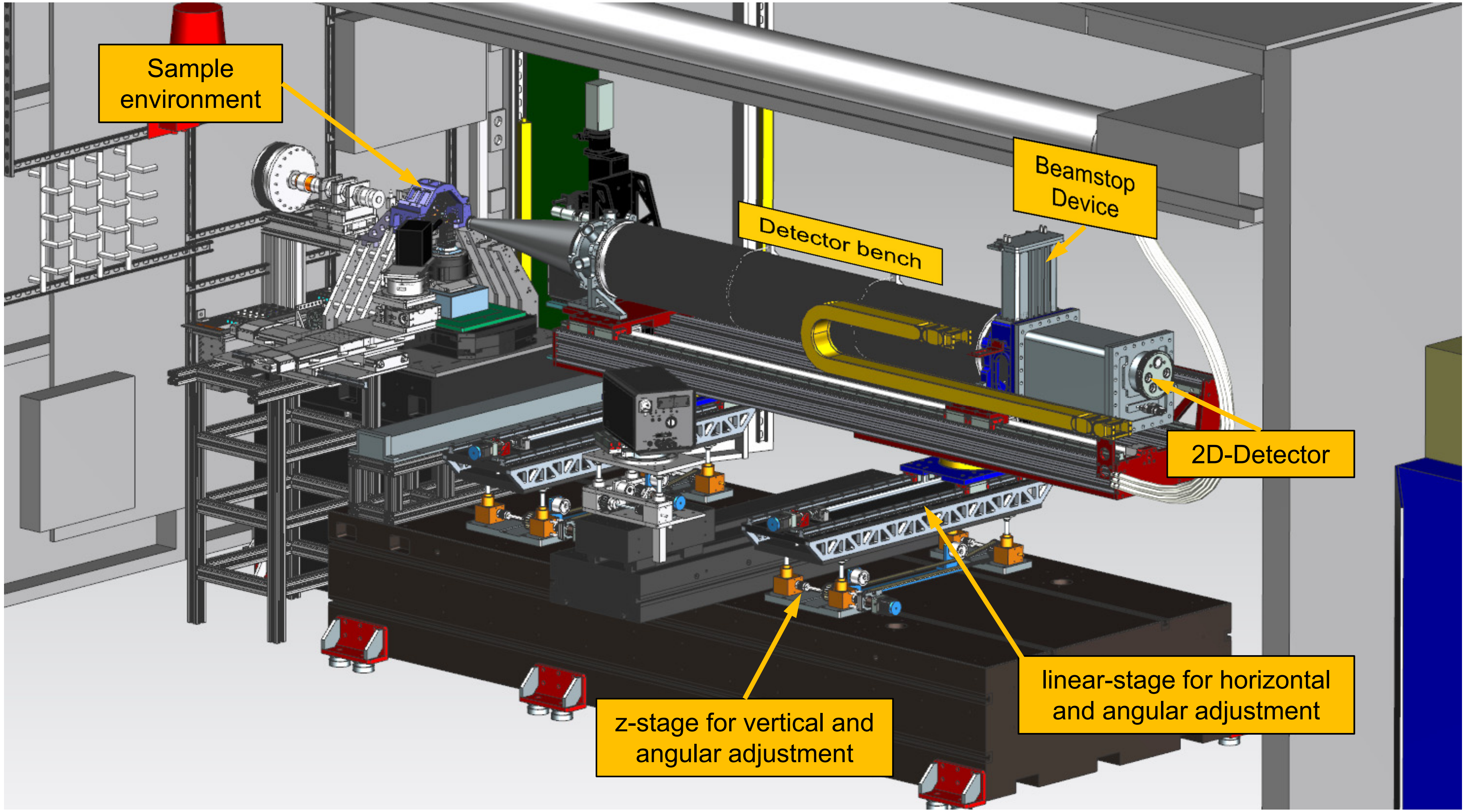



Functionality of the detector bench

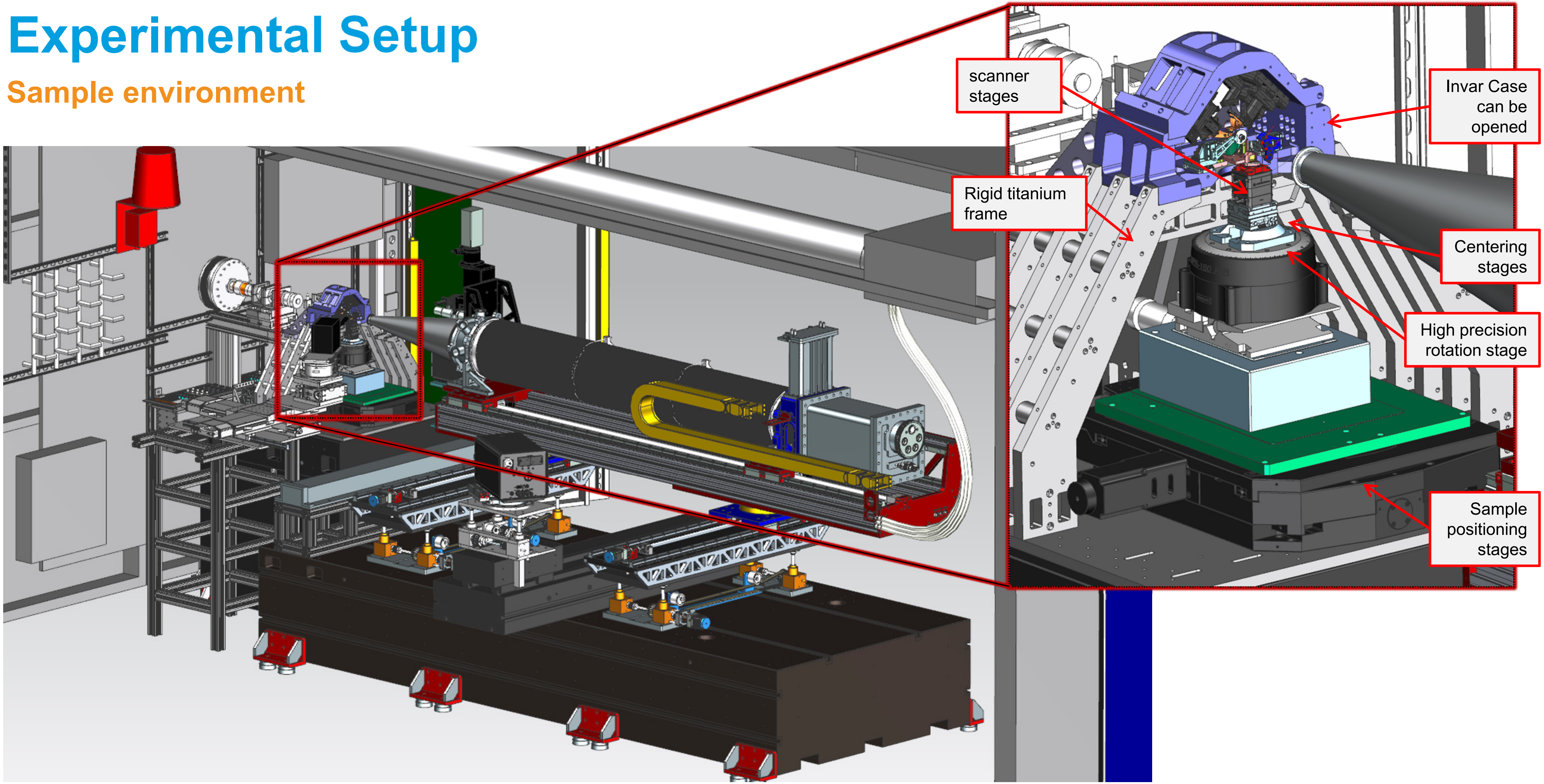
# Experimental Setup

## Overall setup of the Nano probe experimental hutch



# Experimental Setup

## Sample environment



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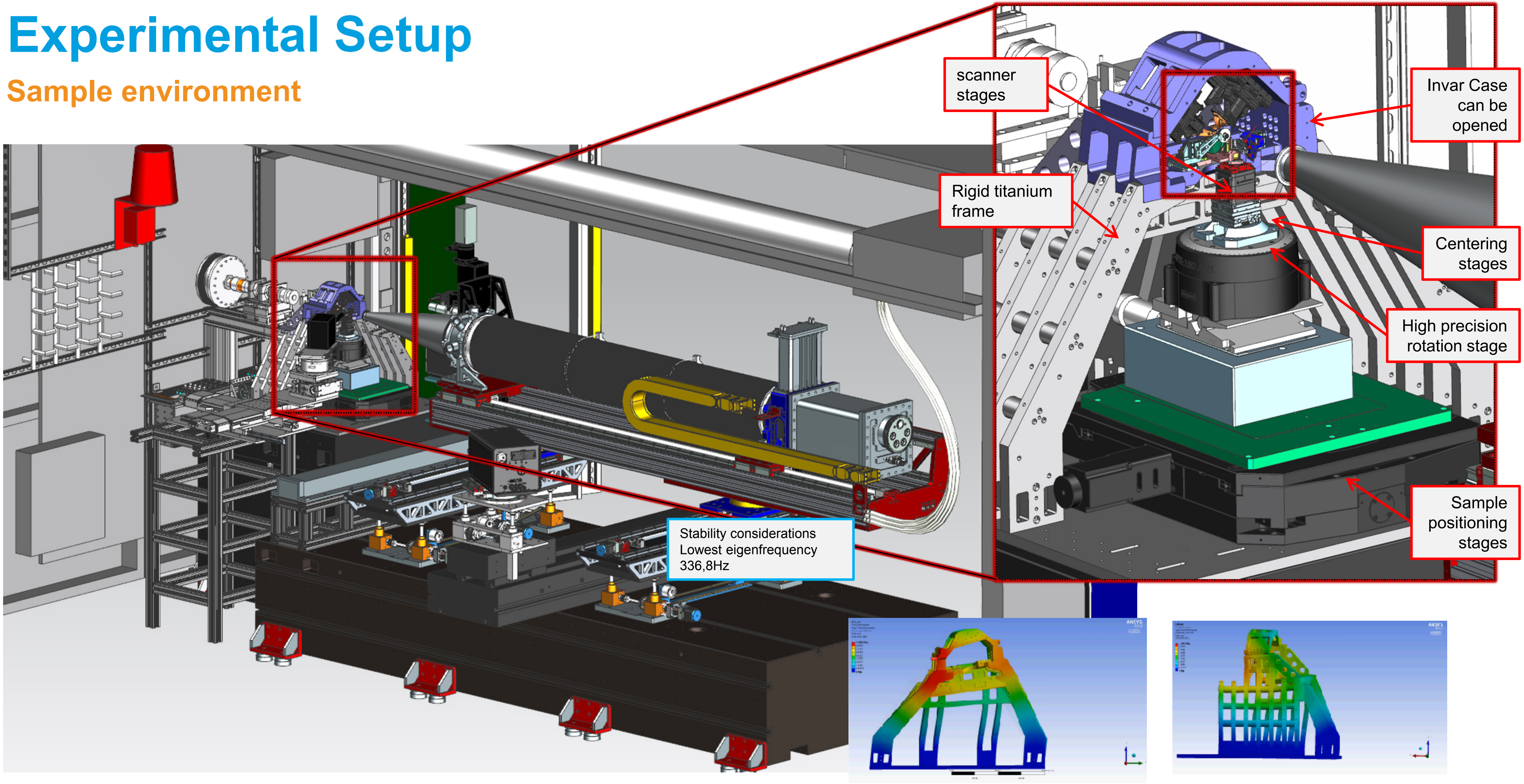
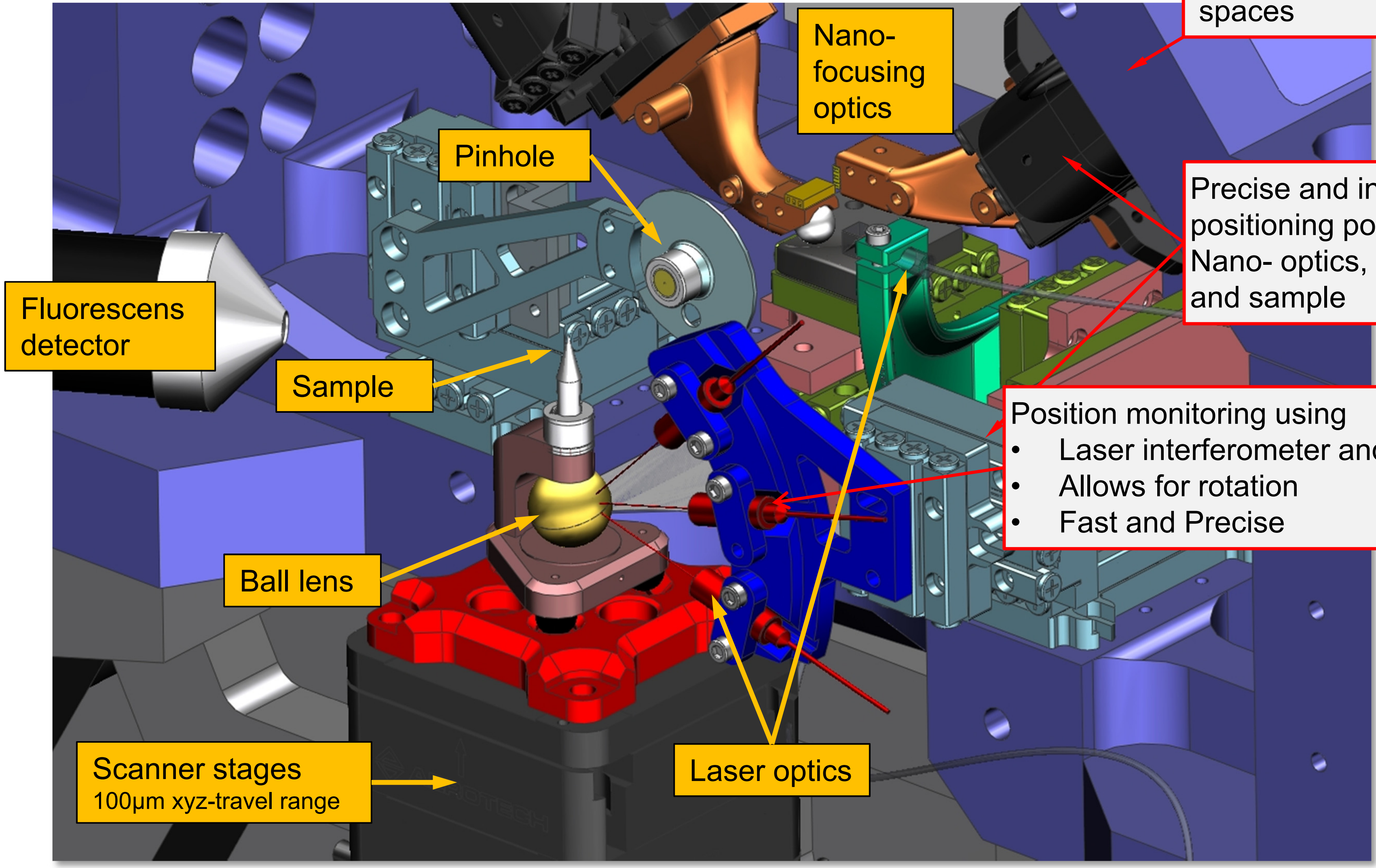
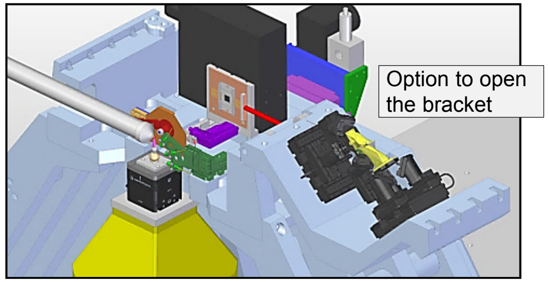


# Experimental Setup

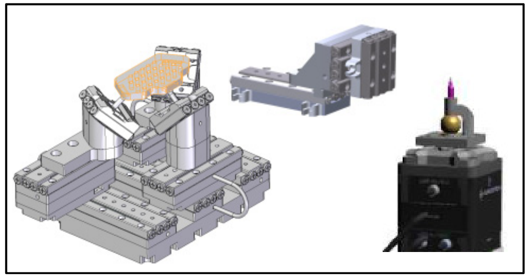
## PtyNAMi standard setup




possibilities to assemble components in the limited spaces

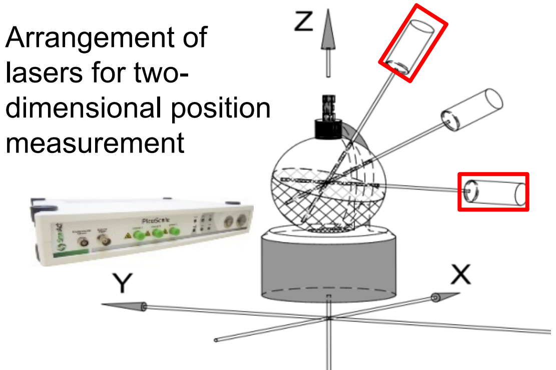



Precise and independent positioning possibilities of Nano- optics, laser- optics and sample



Position monitoring using
- Laser interferometer and Ball-lens
- Allows for rotation
- Fast and Precise

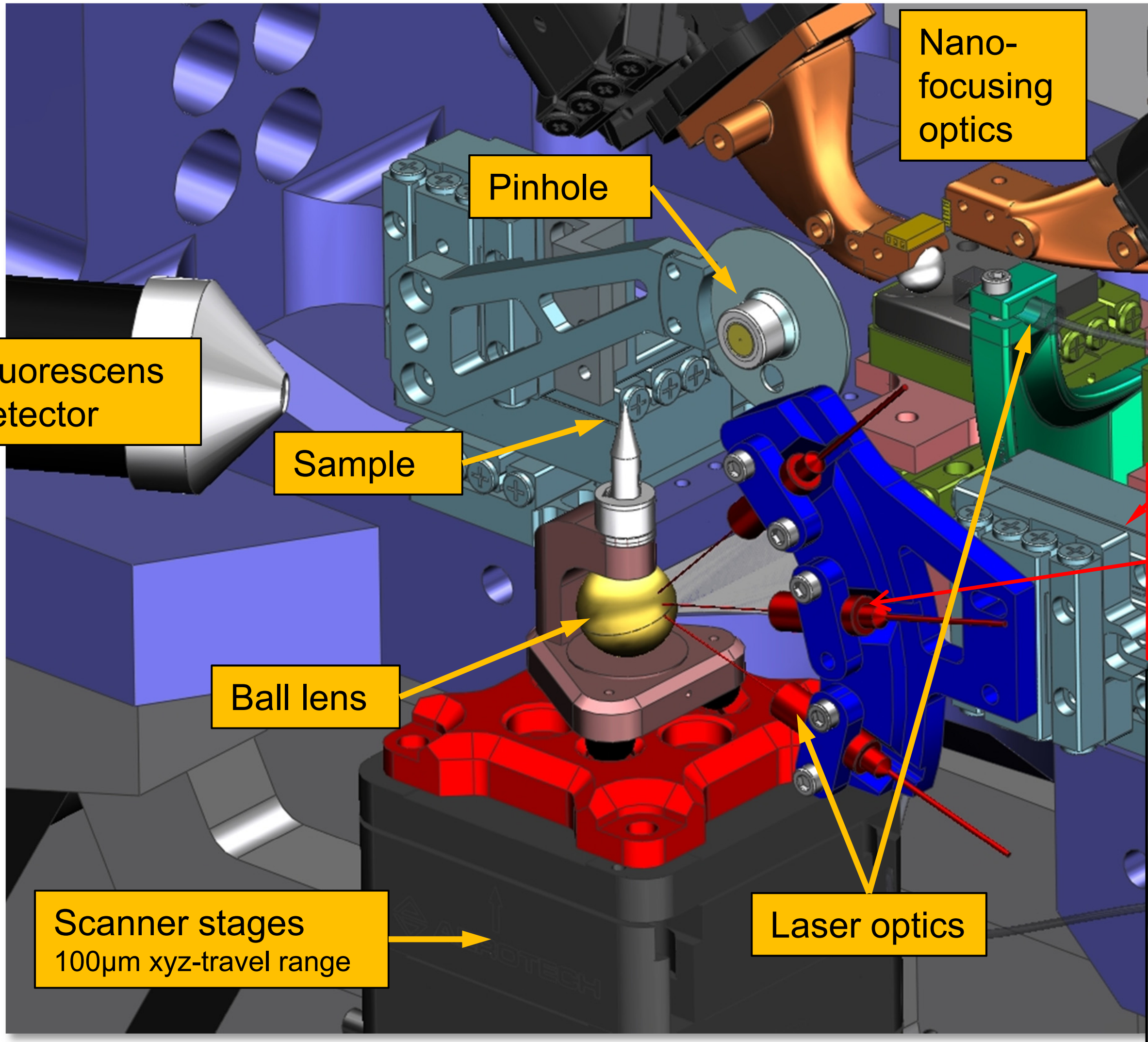
Arrangement of lasers for two-dimensional position measurement



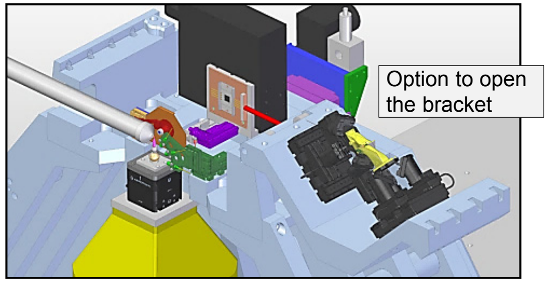

Ball lens with refractive index n=2, is metal-coated on one side, to increase signal quality

# Experimental Setup

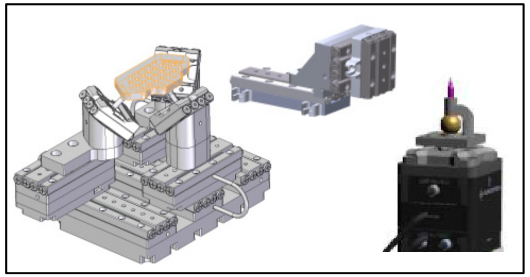
## PtyNAMi standard setup



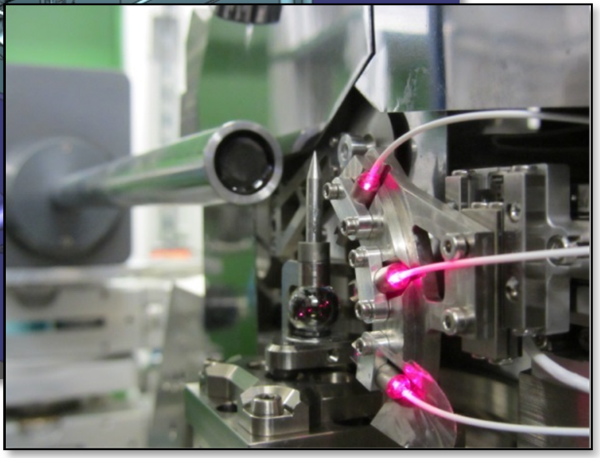

possibilities to assemble components in the limited spaces



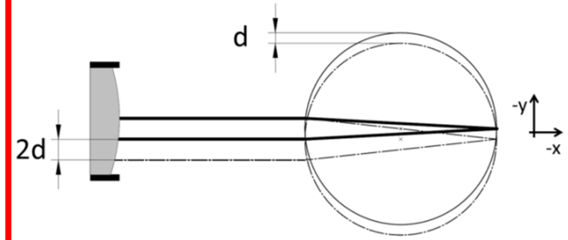

Precise and independent positioning possibilities of Nano- optics, laser- optics and sample



Position monitoring using
- Laser interferometer and Ball-lens
- Allows for rotation
- Fast and Precise



### Ball Lens as a retroreflector




Focal Length f in a Ball Lens

$f = \frac{nr}{2(n-1)}$ $\quad$ $n = 2 \Rightarrow r = f$ → Retroreflection

Our ball lenses:

n = 1.955 @ λ = 1550nm r = 5mm

Usable travel range d:

Good situation: ~1mm (optimised laser alignment)
Real situation: ~250µm

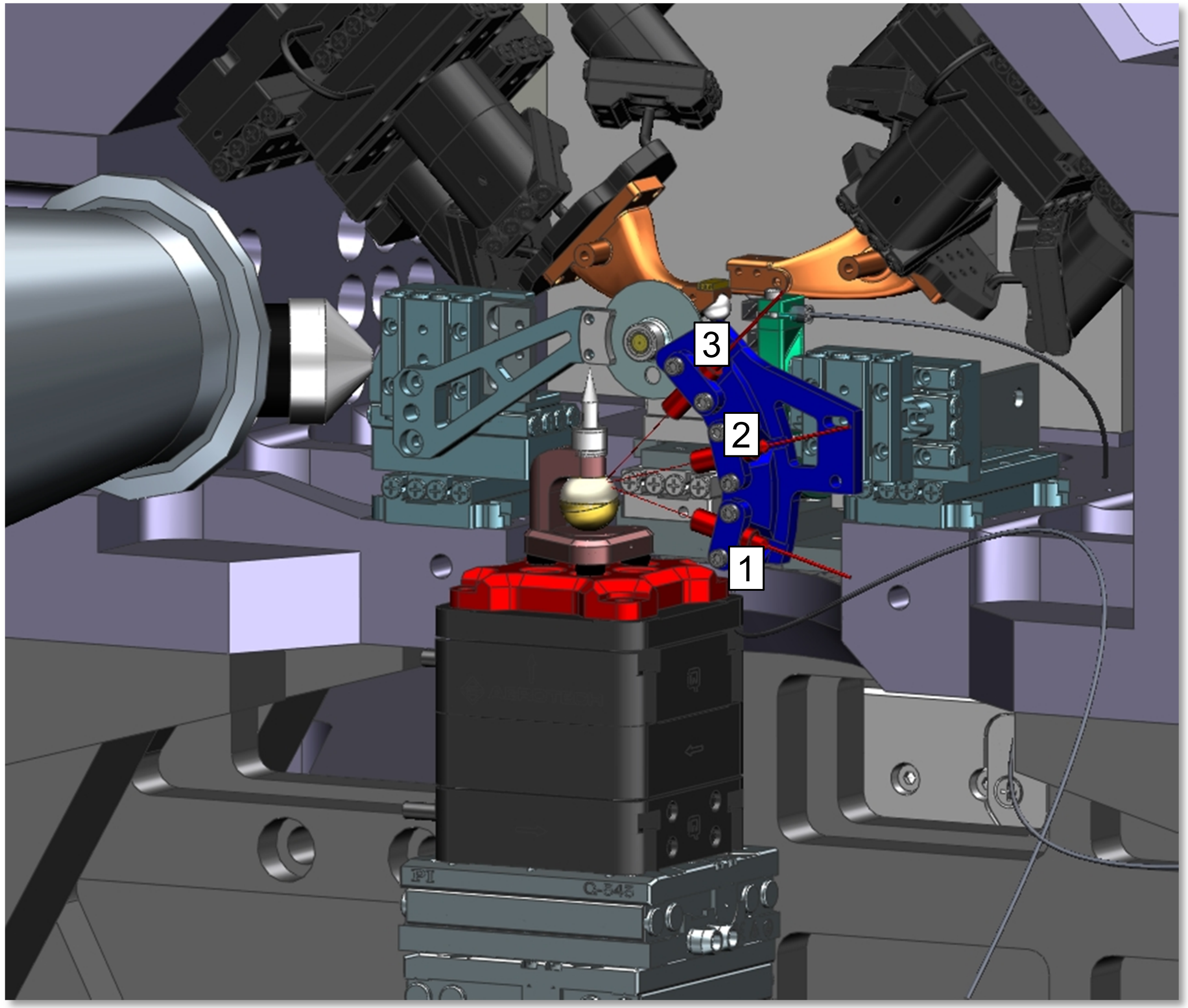


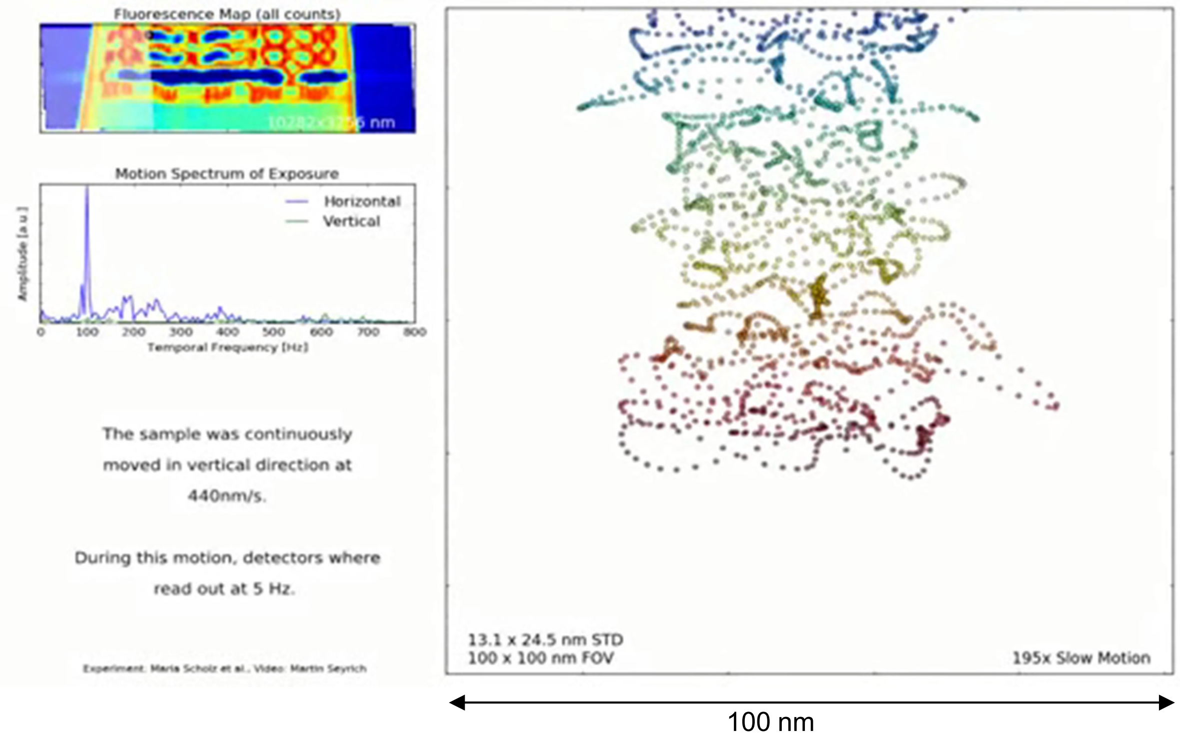
# Position stability

## Some results, measured with the laser interferometer

# Position Stability

## Position information from standard setup obtained by the interferometer



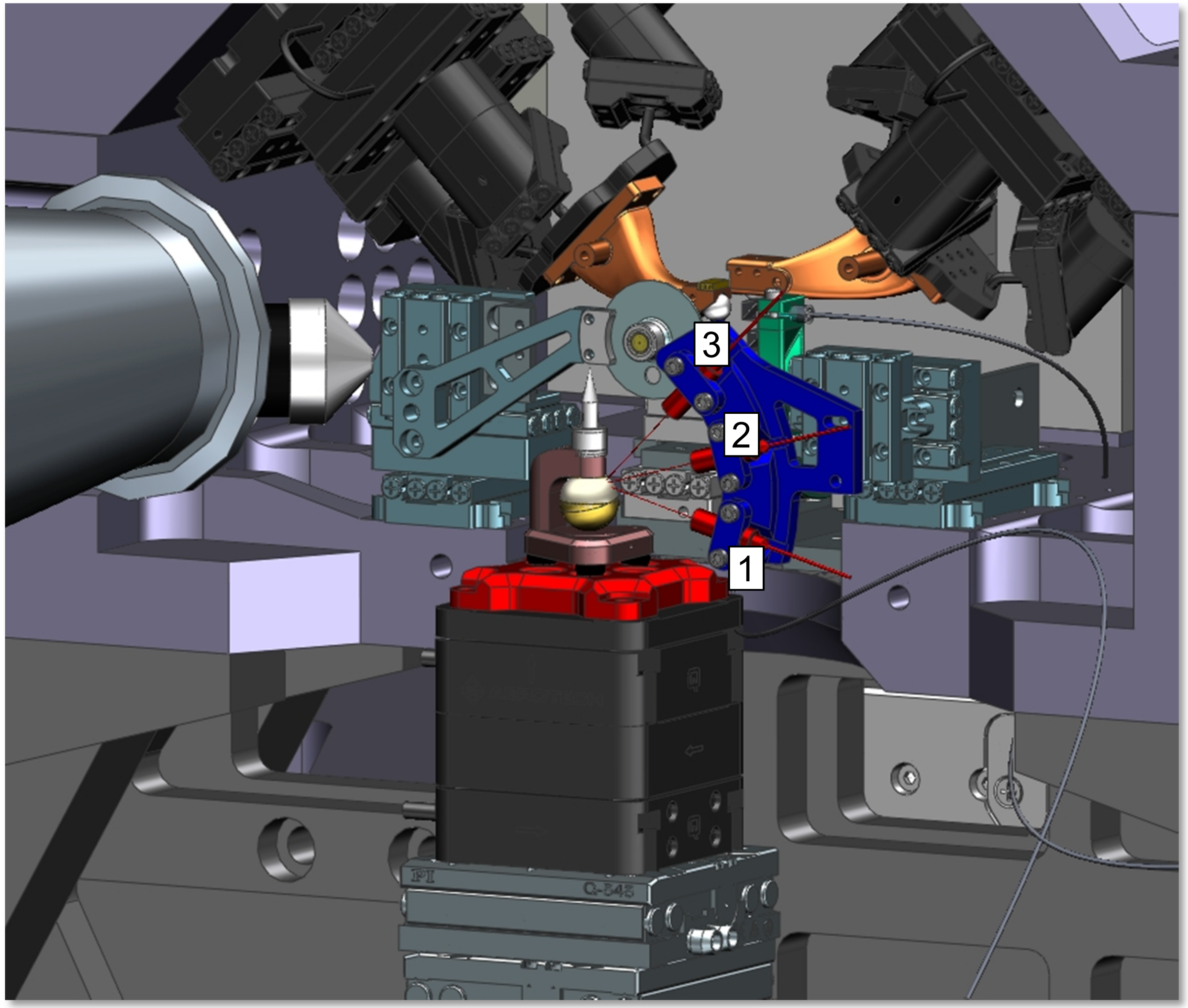



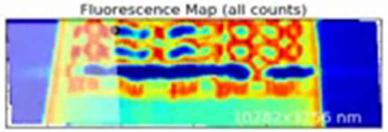

**Measurement conditions**

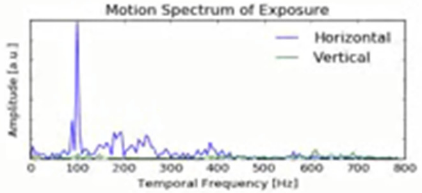
- Measured with laser 1 and 3.
- Laser 2 is used for correction only.
- Position measurements performed during continuous scan
  - Horizontal deviation 24.7nm (rms)
  - Vertical deviation 9.6nm (rms)

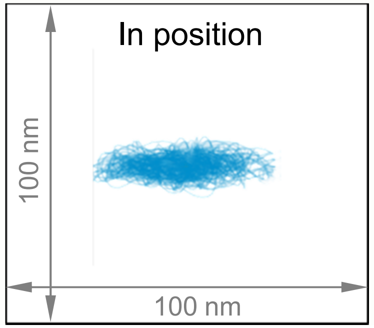
# Position Stability

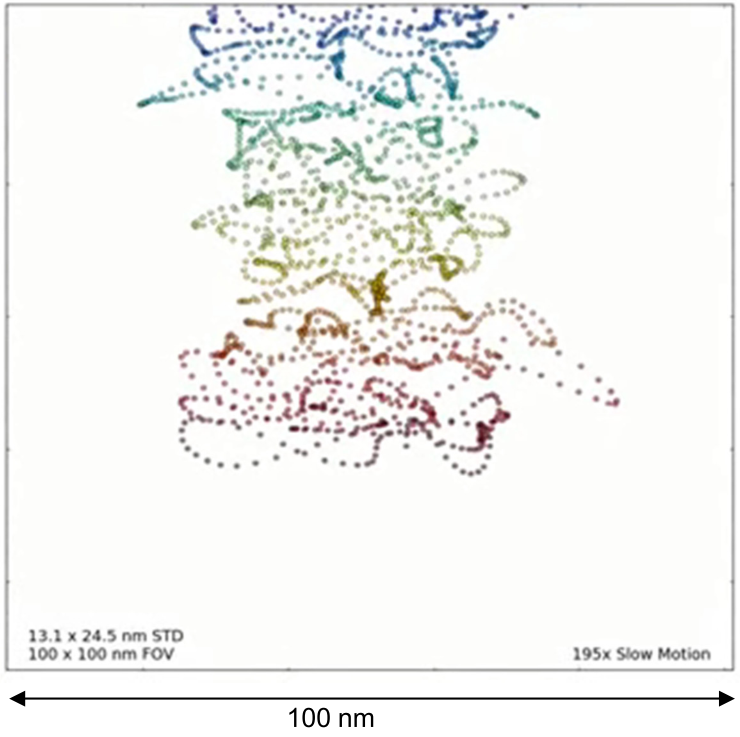
## Position information from standard setup obtained by the interferometer




**<u>Measurement conditions</u>**

- Measured with laser 1 and 3.
- Laser 2 is used for correction only.
- Position measurements performed during continuous scan
  - Horizontal deviation 24.7nm (rms)
  - Vertical deviation 9.6nm (rms)

**Not bad ! But it could be better**

# Position Stability

## Experimental option for an extremely stable setup

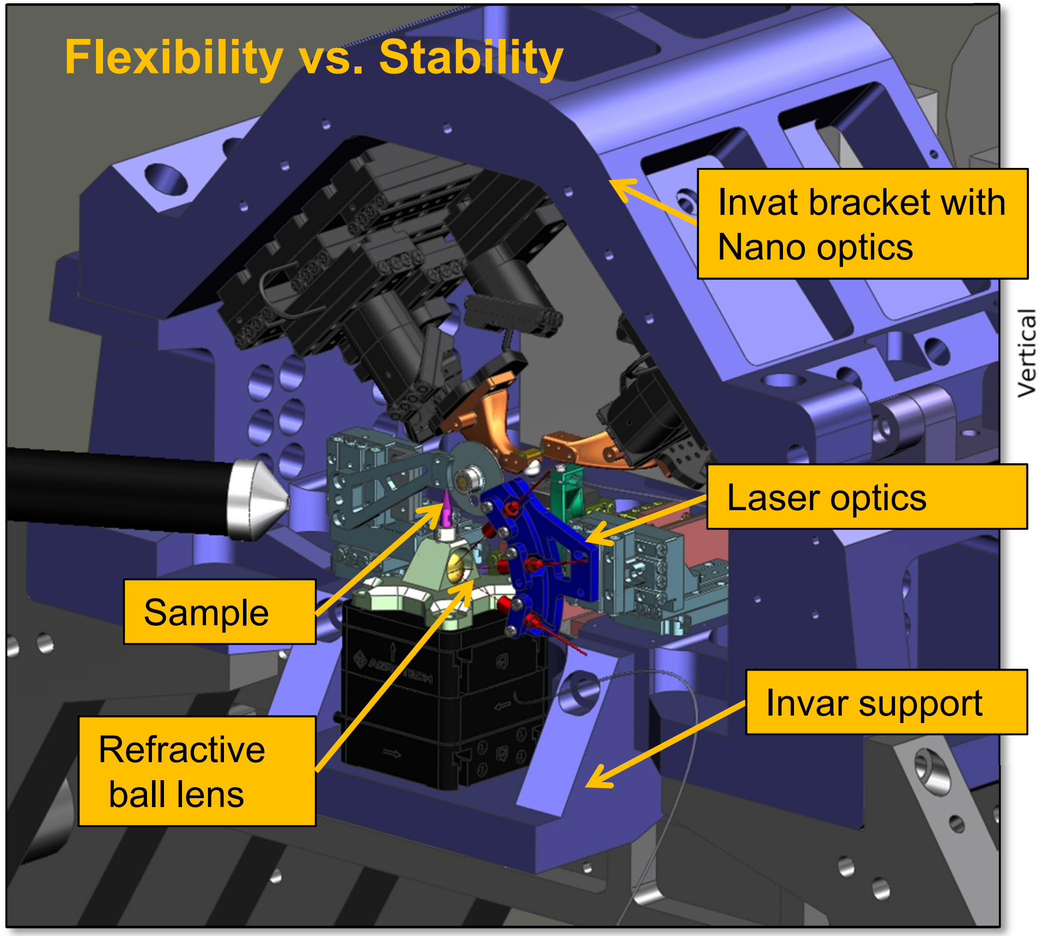
### How to increase stability

- **Removing all sources of vibration**
- **Reduction of the degree of freedom and increase in stiffness.**

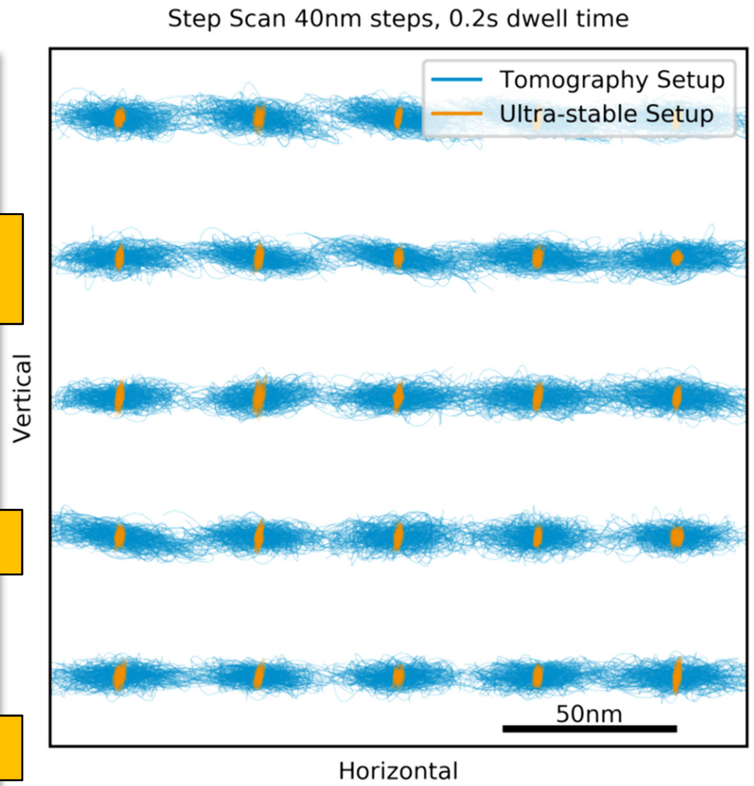
Ultra stable scanner setup for 2D-scan experiments.

# Position Stability

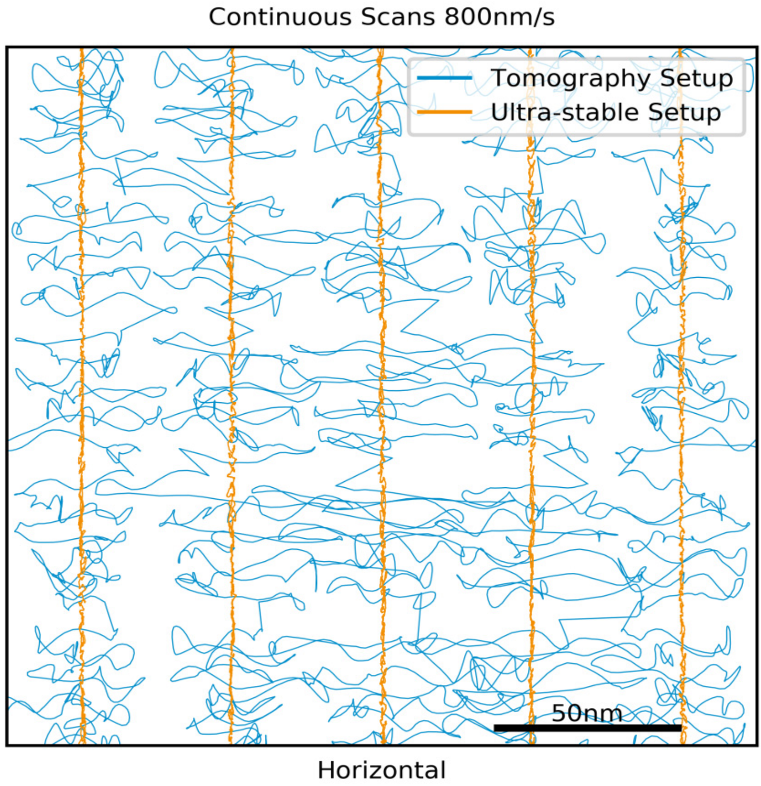
## Experimental option for an extremely stable setup




Ultra stable scanner setup for 2D-scan experiments.




- Blue points: standard Tomography setup.
- Orange points: modified setup
  deviations horizontal 0.67nm (rms)
  vertical 1.5nm (rms)

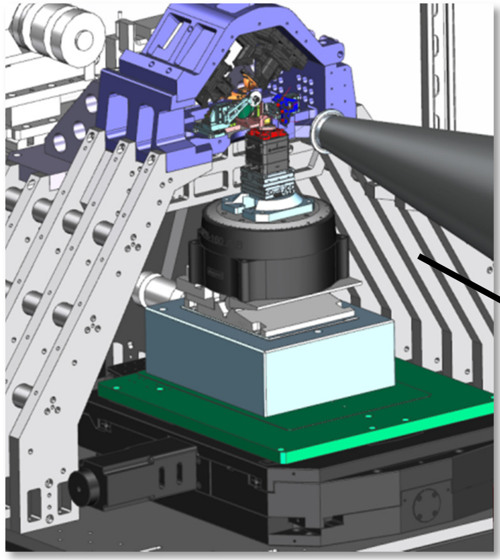



- Blue lines: standard Tomography setup.
- Orange lines: modified setup
  deviations horizontal 0.38nm (rms)

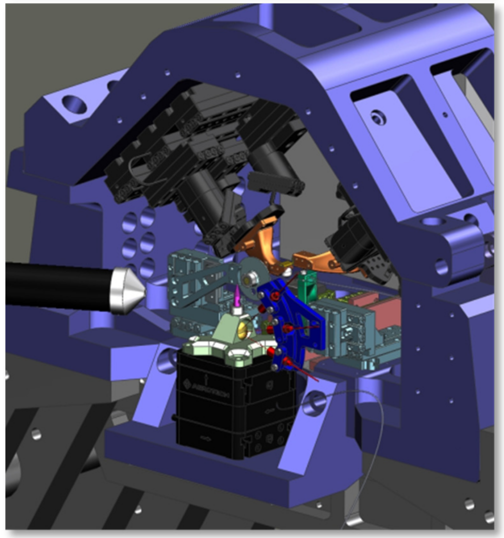
# Position Stability

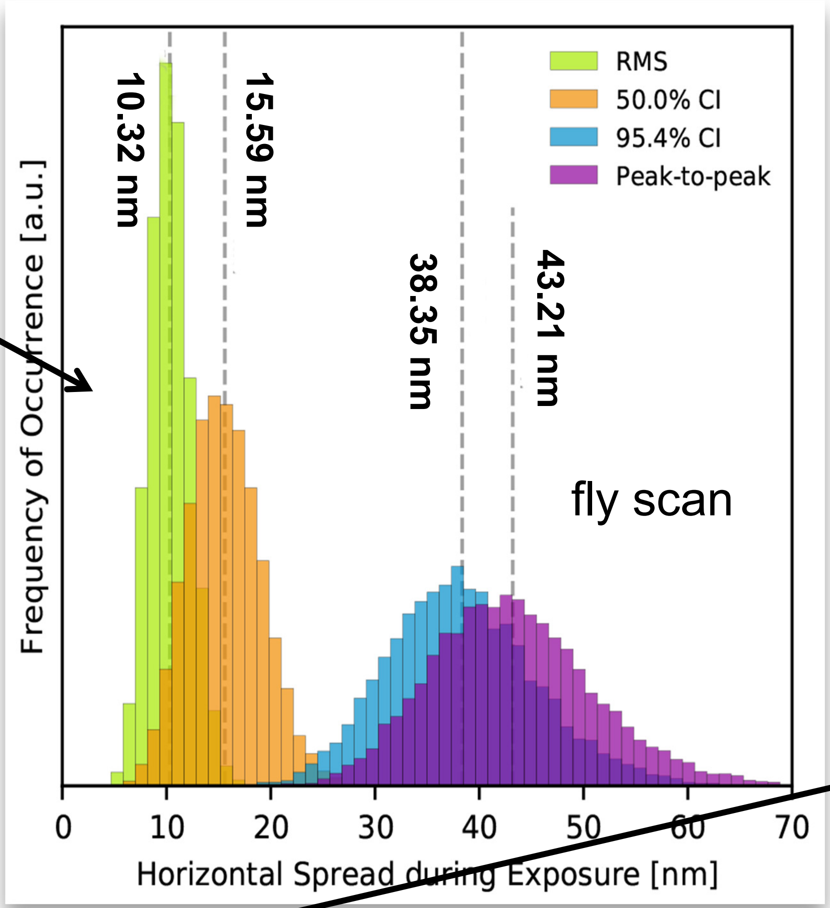
## Comparison between standard setup and modified setup (Flexibility vs. Stability)

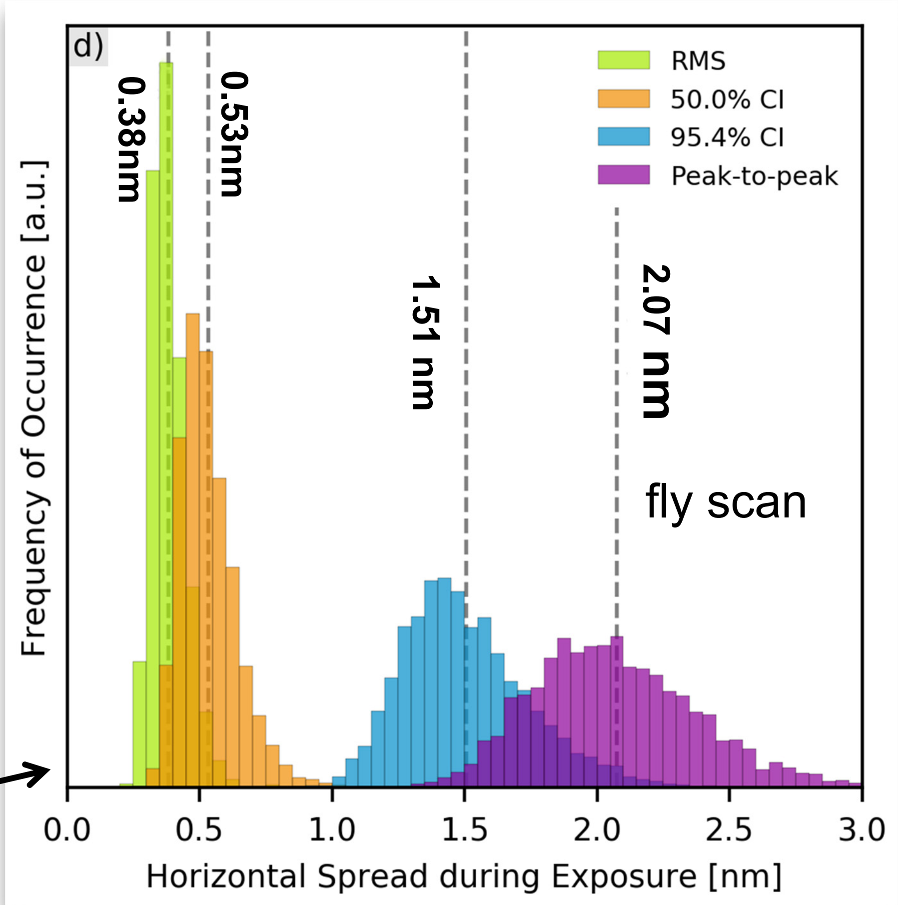
Standard Tomo-setup



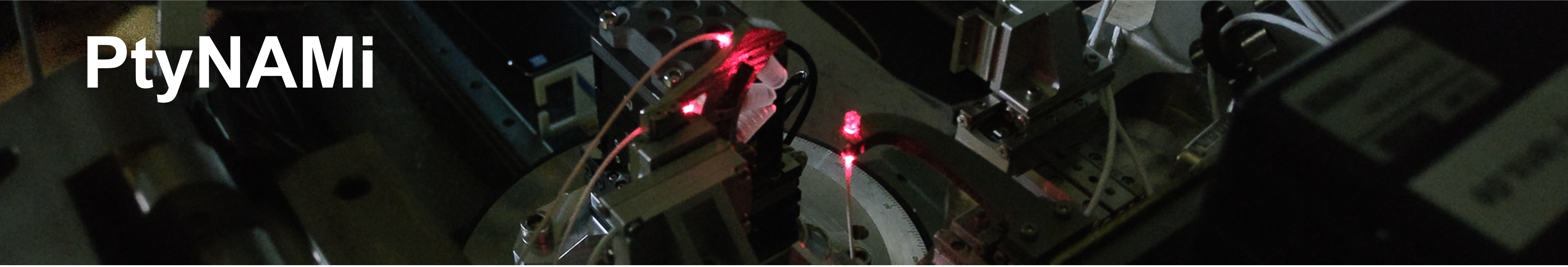
Ultra-stable setup






RMS may be misleading!

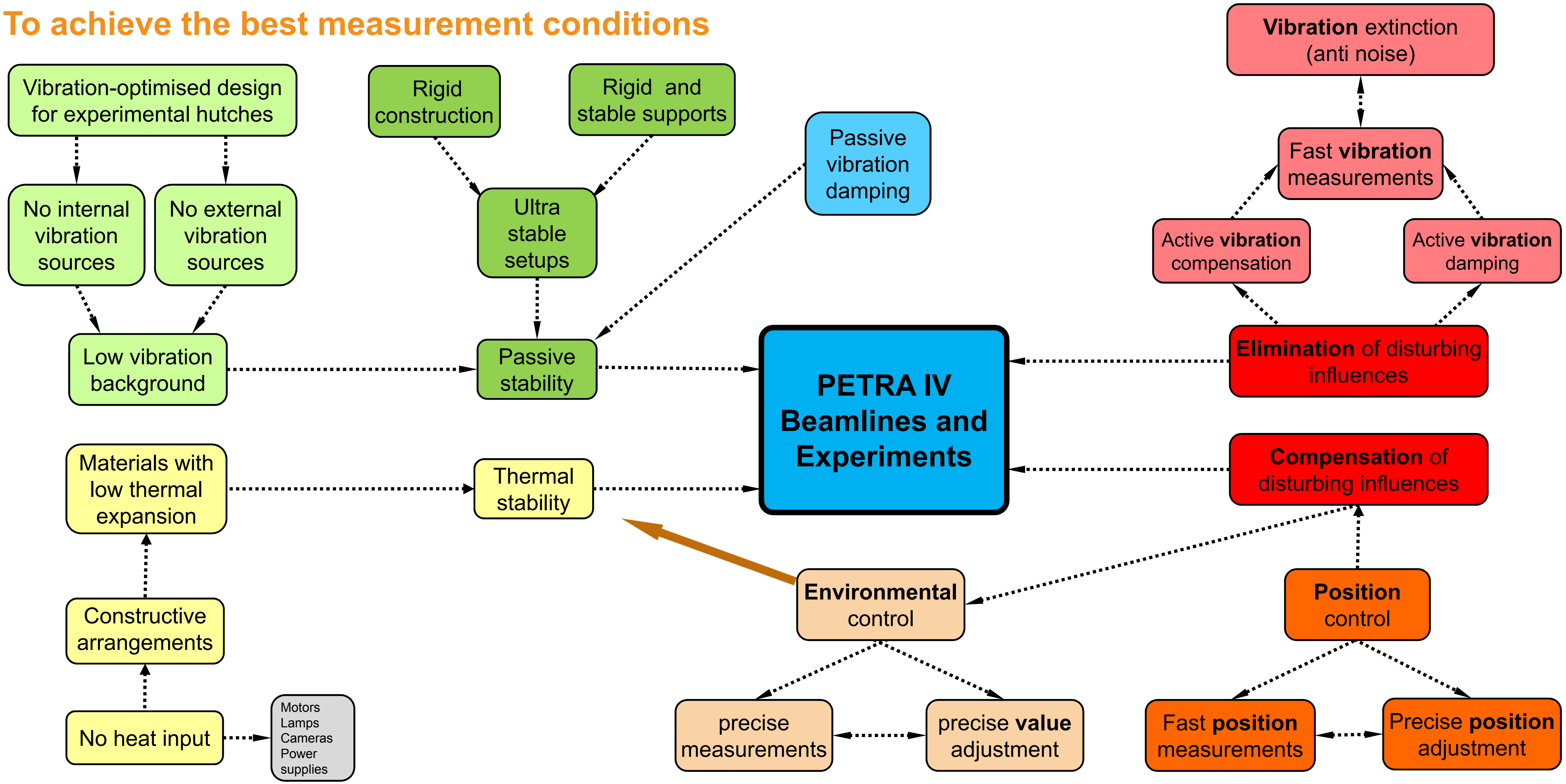



# Stability considerations

## For further improvements

# Stability considerations

## To achieve the best measurement conditions





# Conclusions

- An overview on the experimental setup was given.
- A new adaptive detector bench and its functionality were explained.
- The PtyNAMi setup with interferometric position detection has been presented.
- Two different scanner setups and and its maximum positional stability of 0.38 nm was shown.
- Options for  further improvements in position stability have been identified.

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## Thank you for your attention !

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