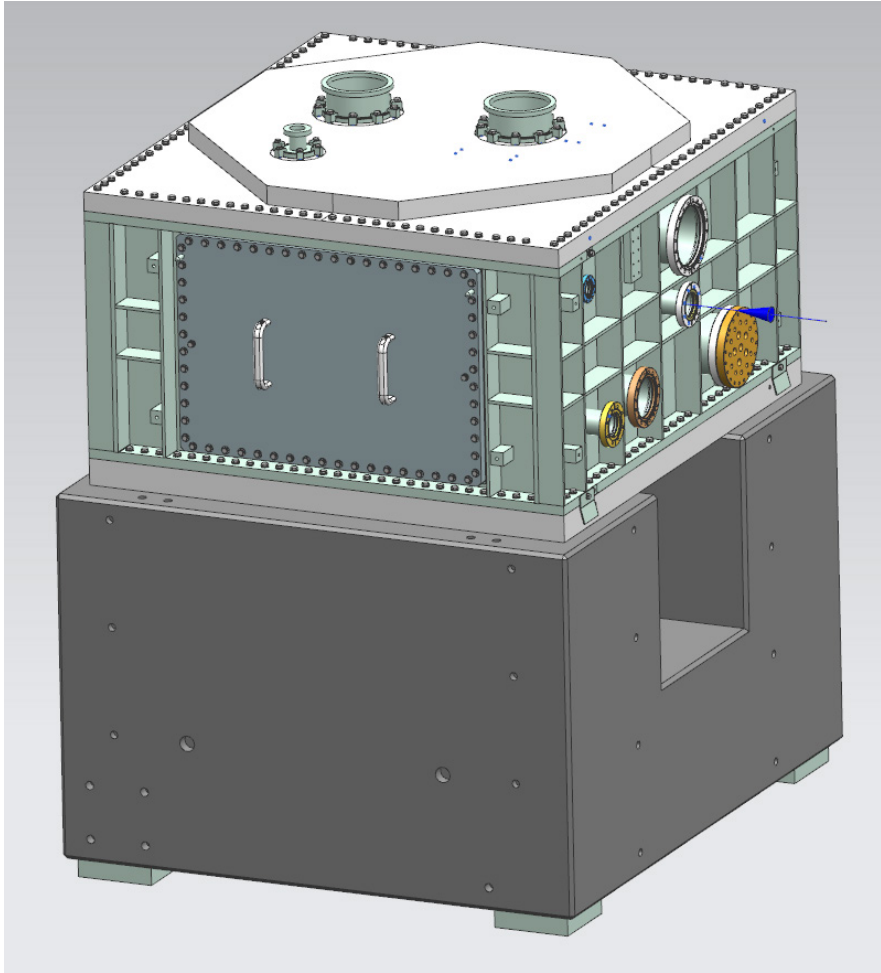


Extension of the High Resolution Monochromator for the Resonant Inelastic X-Ray Experiment at the Petra III Beamline P01



Dimension of the Tank

1,3 m along the beam

1,4 m perpendicular to the beam

0,8 m height

Where to go

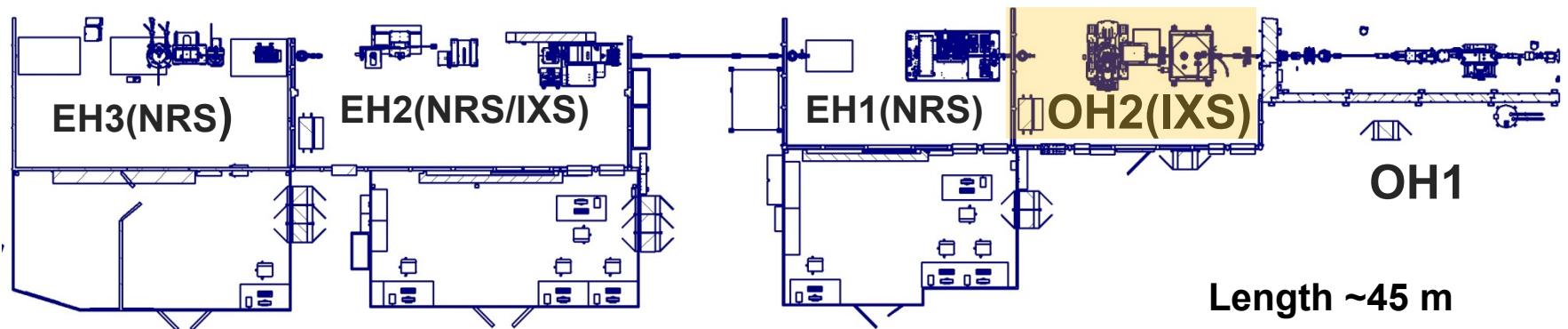


**Max von Laue Hall
since 2009**

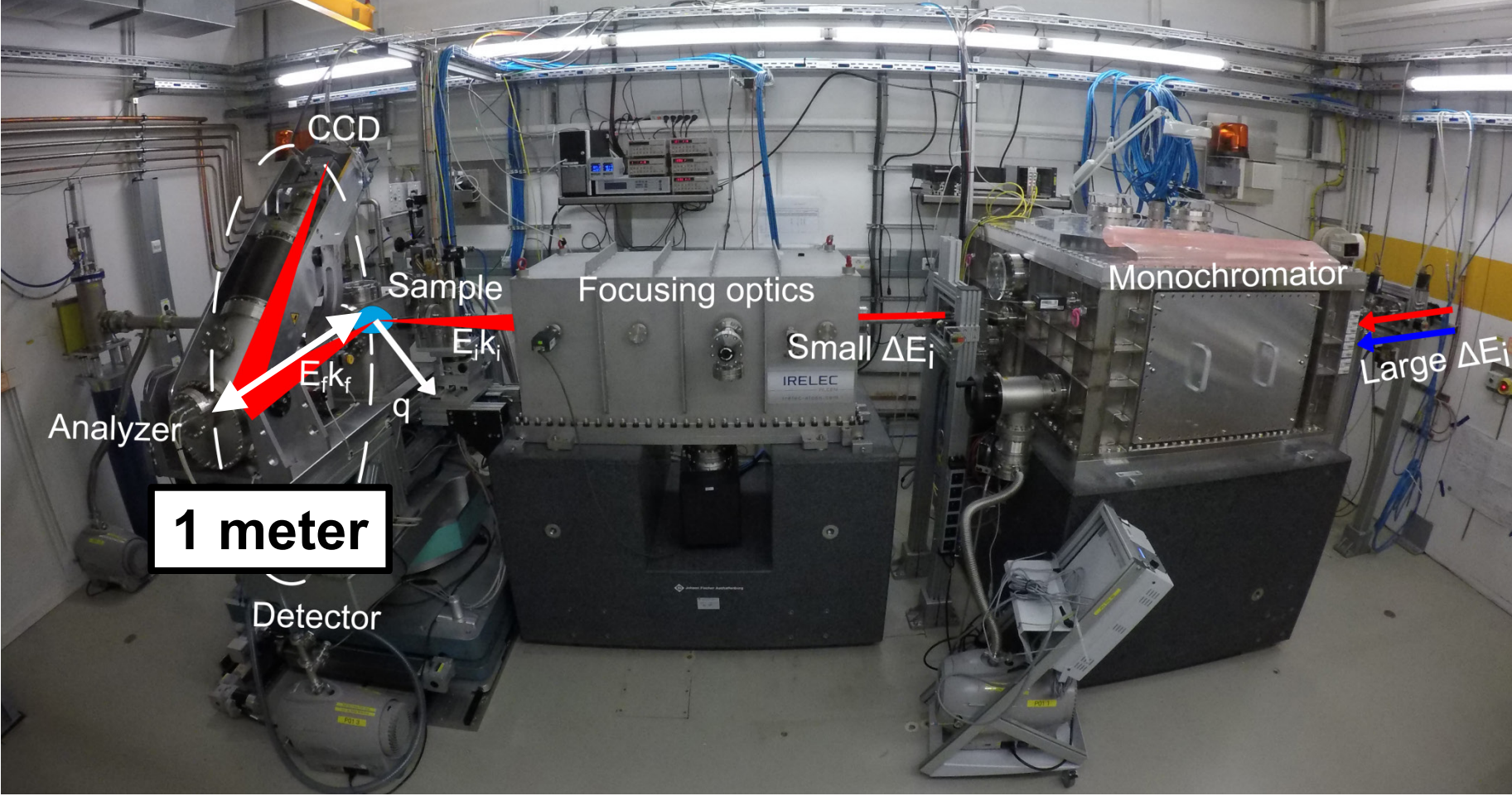
**P01-Dynamics
Beamline
with 2 x 5 m
Undulators**

Beamline P01

High-resolution x-ray spectroscopy (2.5 – 80 keV)



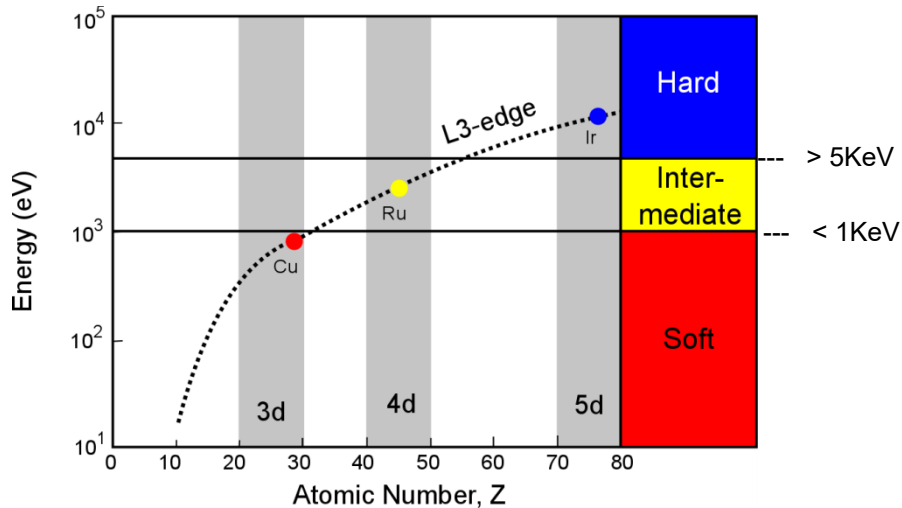
RIXS instrument at P01



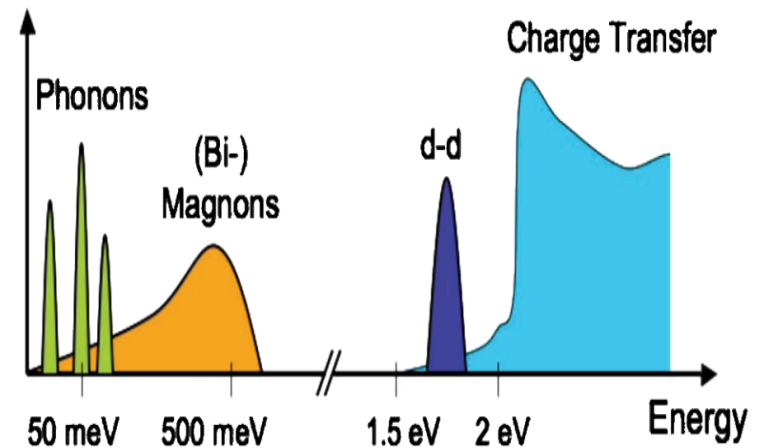
Science and Motivation

Partnership with Max Planck Institute Stuttgart since 2015

Ruthenates will be potentially used for storage of information (quantum computing) and for superconductivity



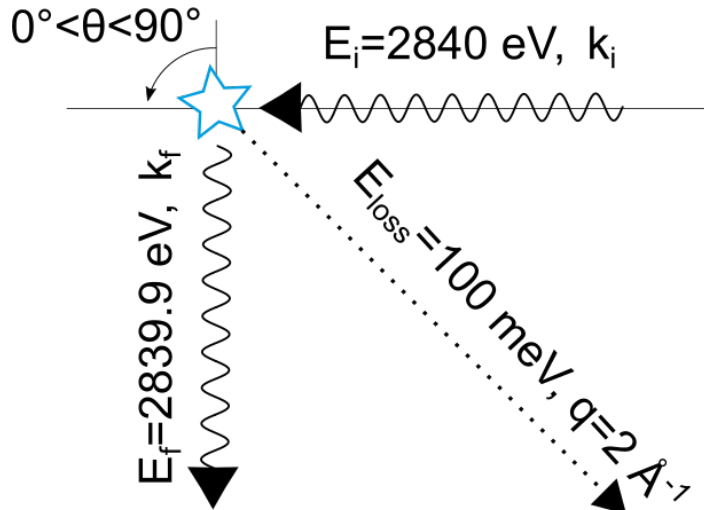
Graphs by Hlynur Gretarsson



Physical phenomena that are not understood.
To support theoretical models, as many different variables as possible should be determined by the experiments

-> high energy resolution at 2.84 keV is needed
-> everything has to be put in high vacuum (10^{-7} mbar)

Challenges



Small bandwidth of incoming energy

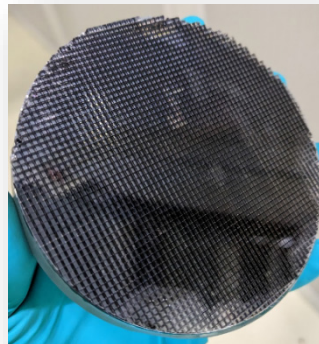
-> High Resolution Monochromator
 $\Delta E = 60 \text{ meV}$

-> angular resolution
of crystal rotation
 $< 500 \text{ nrad}$

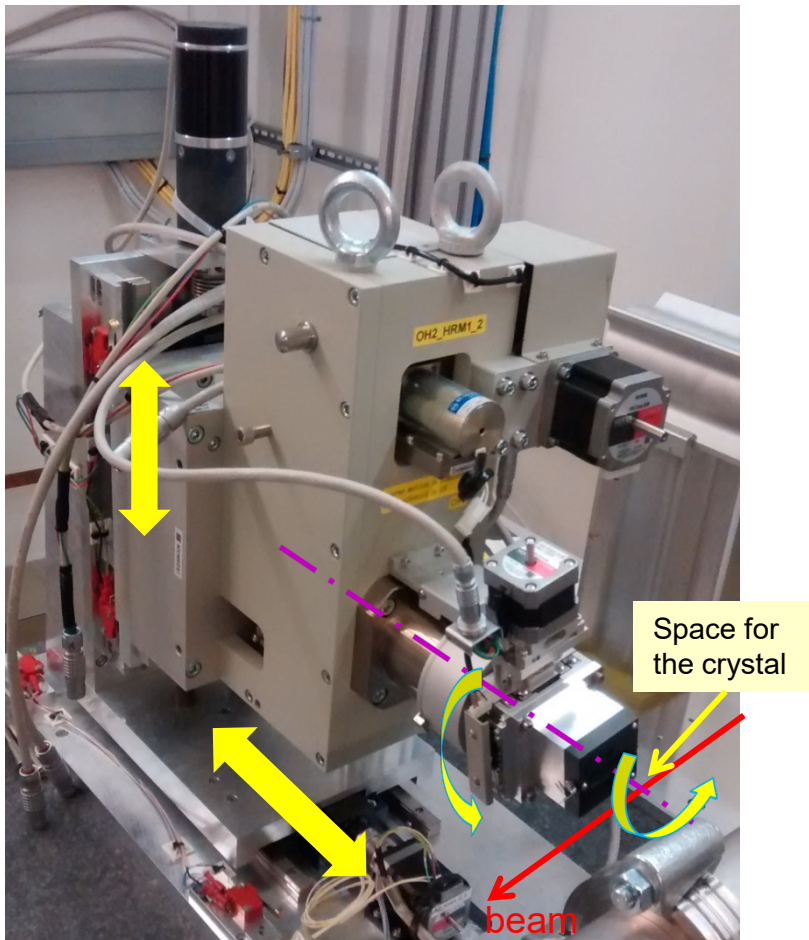
Graph by Hlynur Gretarsson

High resolution measurement of
outcoming energy

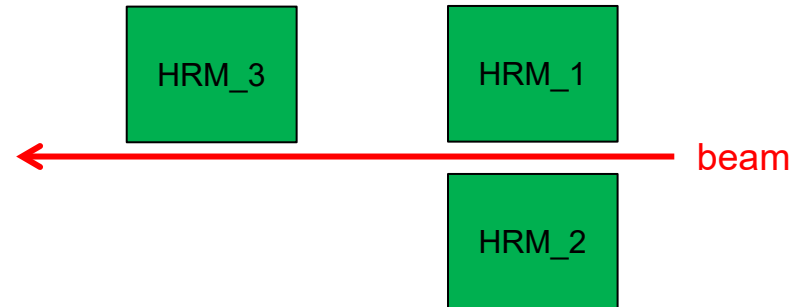
-> High Resolution Analyzers
 $\Delta E = 60 \text{ meV}$



Previous high resolution monochromator (in air)



3 single setups (top view)



- Modifying of existing Kohzu KTG-15MA possible, but only for to 10^{-4} mbar ($\neq 10^{-7}$ mbar). Limit also for new KTGs.

Costs: modifying 4.300€
brandnew 35.000€

- Some values of existing Kohzus:
 - wobble 1 arcsec
 - resolution 120nrad (full step of stepper motor)
 - $\pm 2^\circ$ range fine
 - 360° with clutch and coarse motor

Requirements

Precise and robust bearing

- Range of rotation $\pm 20^\circ$
- Wobble 1 arcsec ($4,8 \mu\text{rad}$) within $\pm 5^\circ$ rotation, -> max. $5 \mu\text{m}$ radial and axial runout
- Possible load of 6 kg
- Friction has to be considered – 500 nrad resolution

High resolution actuator with long travel range

- Range of rotation $\pm 20^\circ$ must be possible, combination of coarse and fine?
- 500 nanorad resolution
- Push-/pulling force of approx. 10 N
- Possibly compact and light

Requirements

Measurement system

- Range of rotation minimal $\pm 20^\circ$
- 500 nanorad angular resolution

General

- All components have to be high vacuum compatible (10^{-7} mbar)
- No outgasing – no window between the ring and the HRM
- Complete setup should be small – size of vacuum tank, vacuum pumps

High precision bearing for 10^{-7} mbar from Mahr

Original design by
Hans-Bernhard
Peters (ZM1-DESY)

Specification:

5 μ m axial and
radial runout

1 μ m achieved



Housing
stainless steel
 \varnothing 38mm
Length 120mm

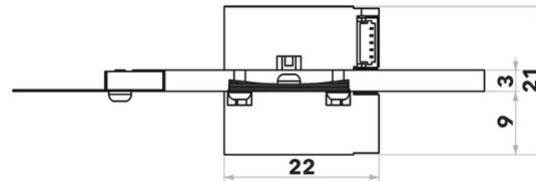
Ball Cage, bronze

Axial Bearing, bronze

Balls
stainless steel, \varnothing 3mm

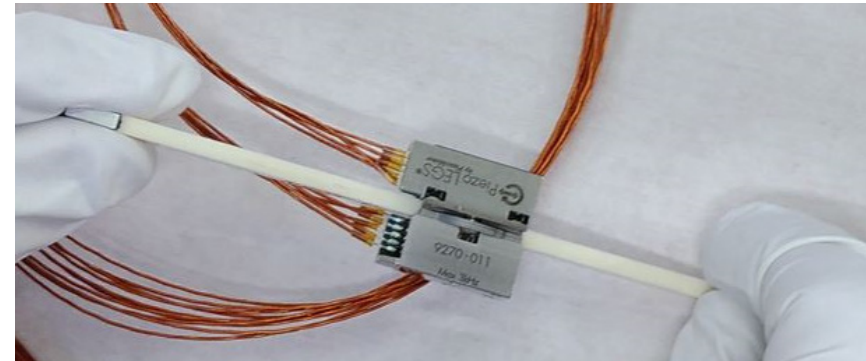
Shaft
stainless steel, \varnothing 16mm

PiezoLEG



<https://piezomotor.com/>

- Sub-nanometer movement
- Compact and light (29 g)
- 20 N push- and pulling force
- Ceramic bar 110 mm available
 - > Travel range ~80 mm
- High vacuum compatible
- No backlash



Renishaw RESM

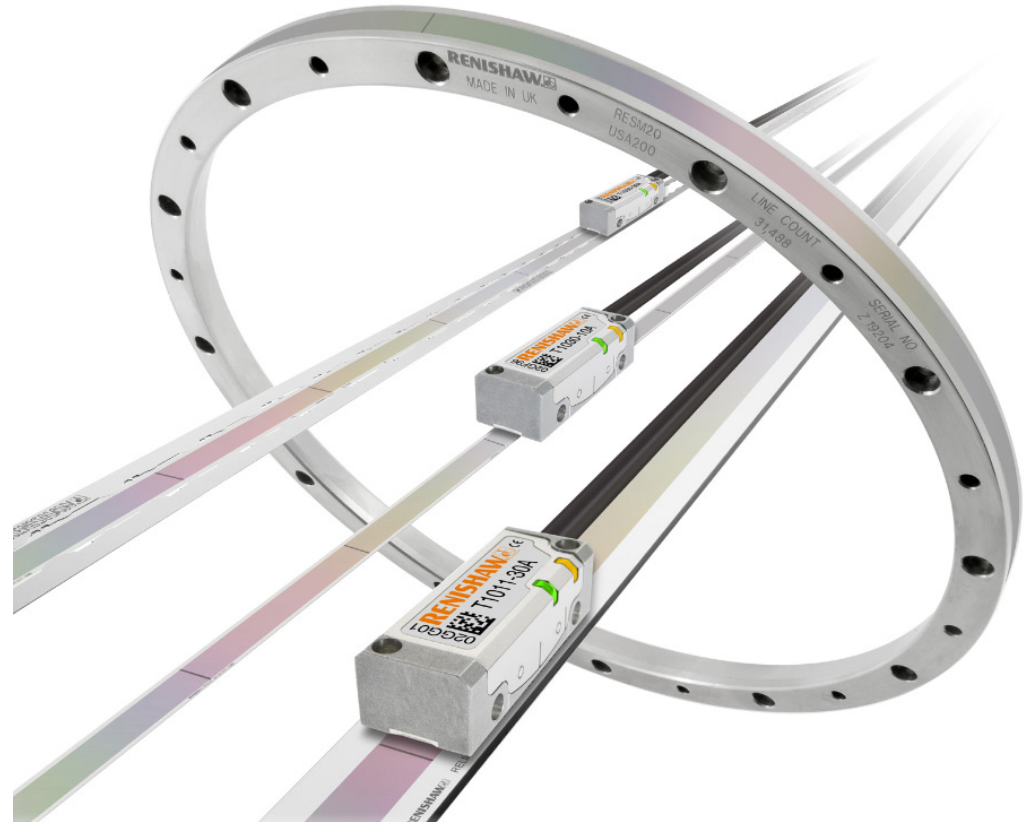
Ring diameter for our project
200 mm

The interface from NANOS
offers interpolation to 1 nm
resolution

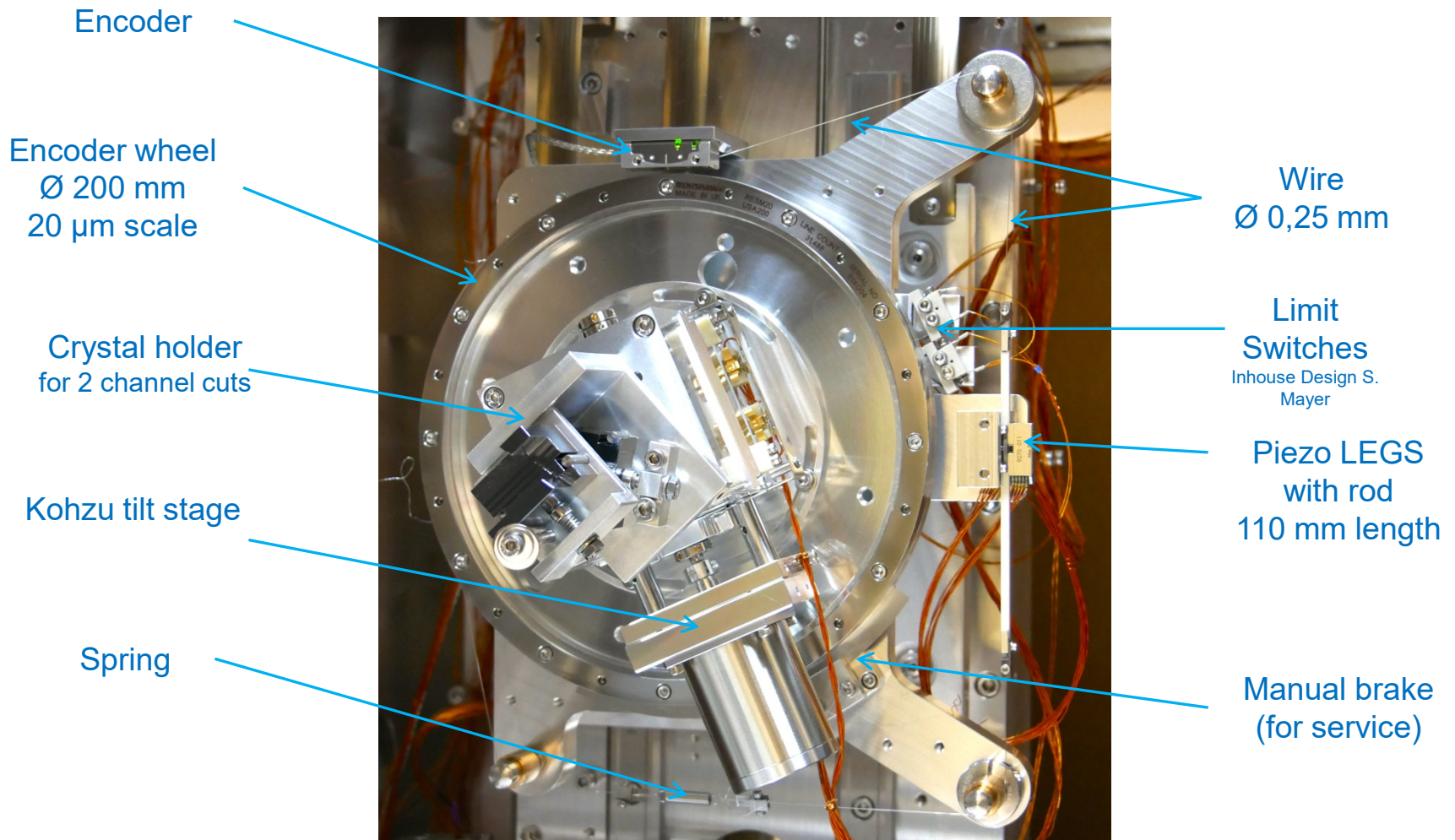
With a radius of 100 mm
and a resolution of 1 nm

10 nanorad
angular resolution is
possible

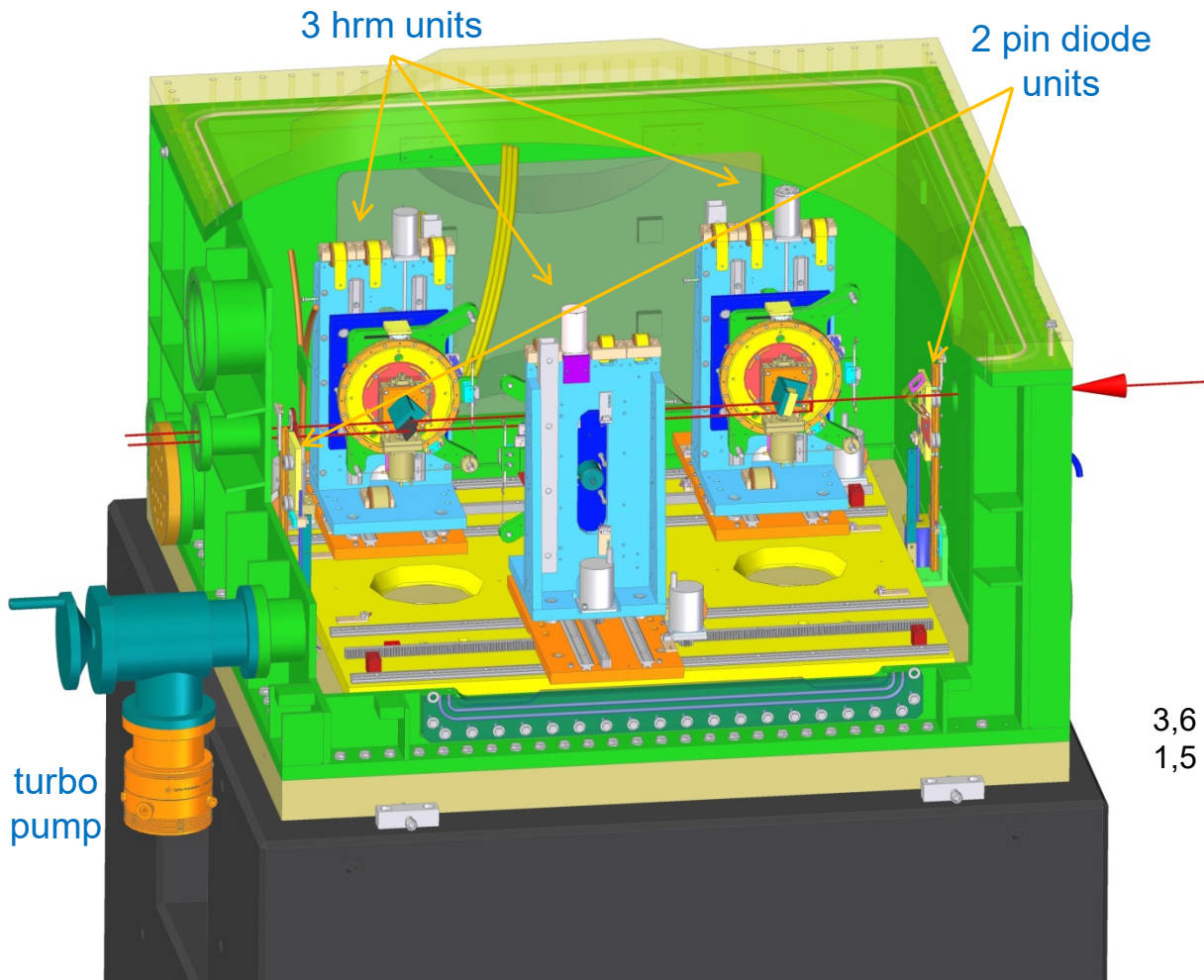
500 nrad is required



Piezo driven goniometer



IXS HRM, 1st version, 100 meV ΔE



Tank

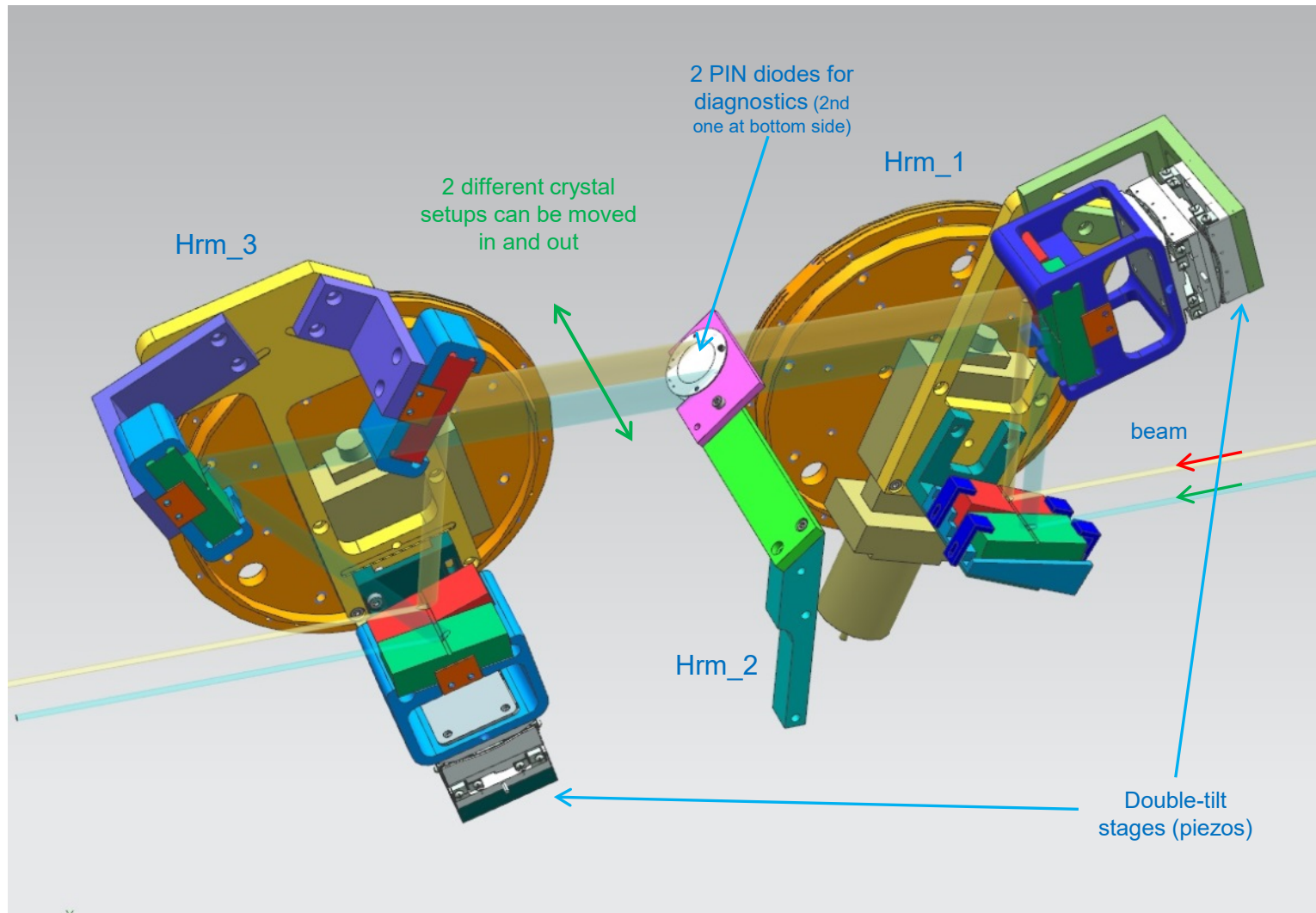
1,4 m x 1,3 m x 0,8 m = 1,45 m³

Body stainless steel
Top / Bottom Aluminum

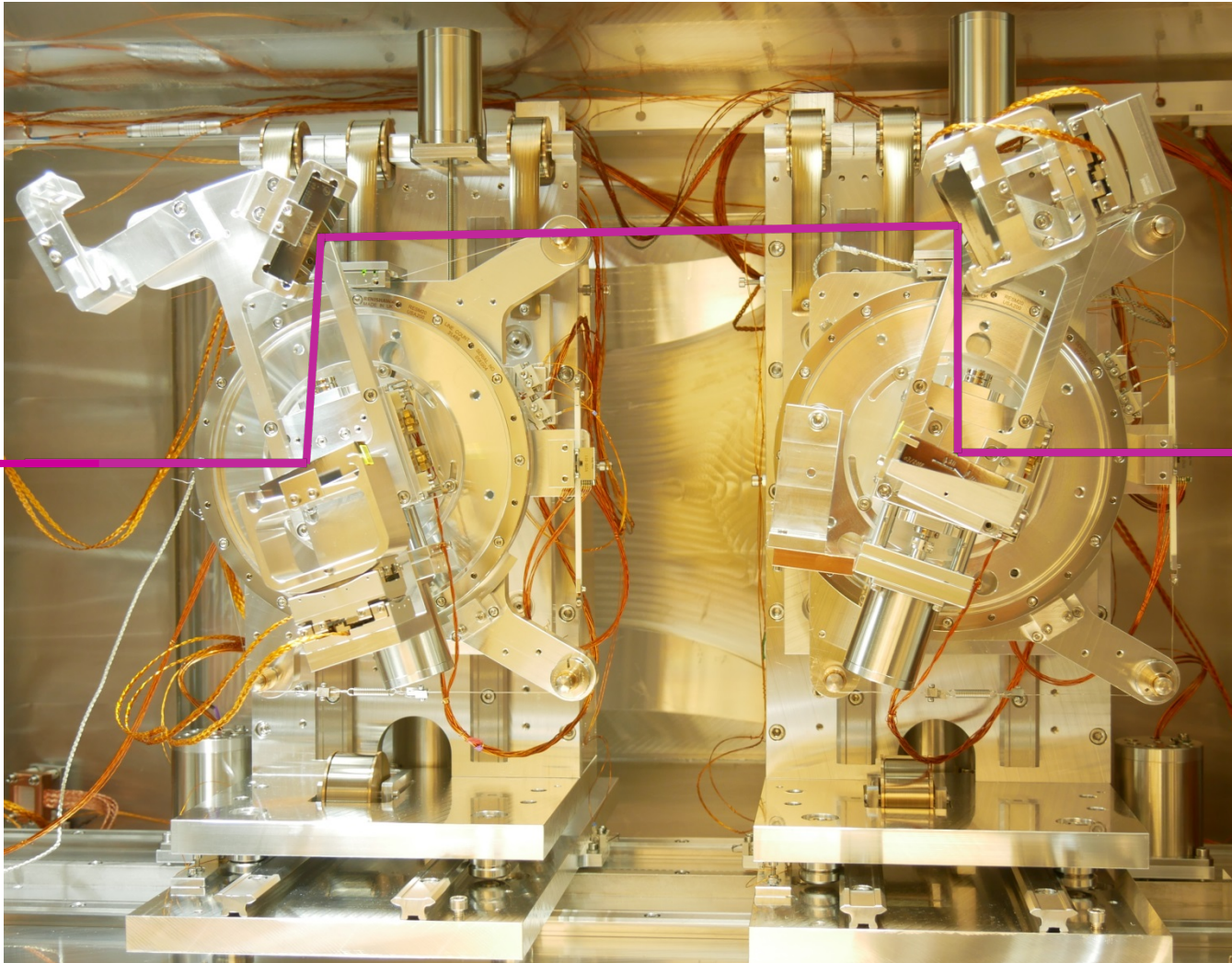
Vacuum

$3,6 \times 10^{-7}$ mbar with two 300 l Getterpumps
 $1,5 \times 10^{-6}$ mbar with one 300 l Turbopump

New setup with four crystals, 60 meV ΔE

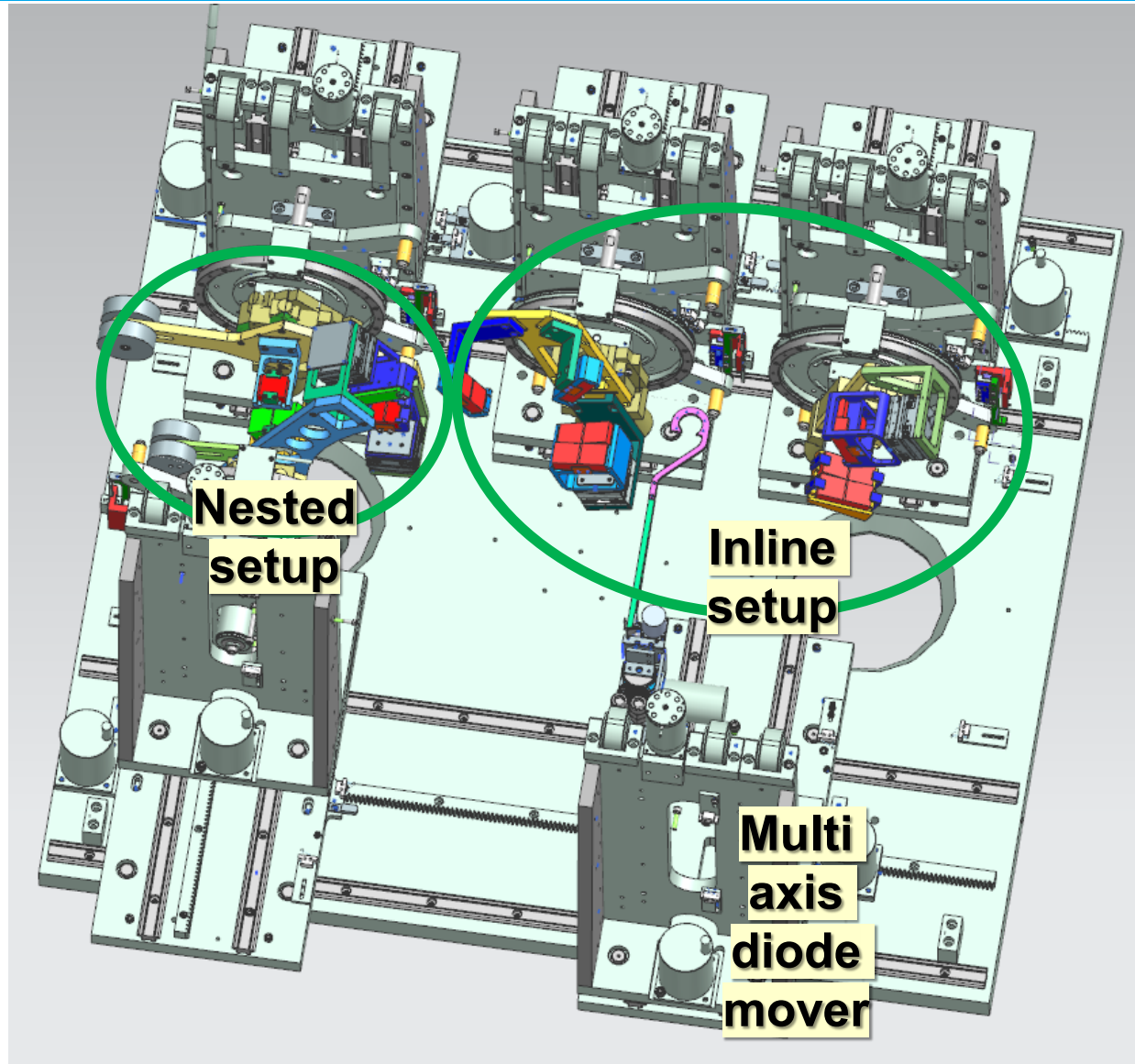


Setup with four crystals

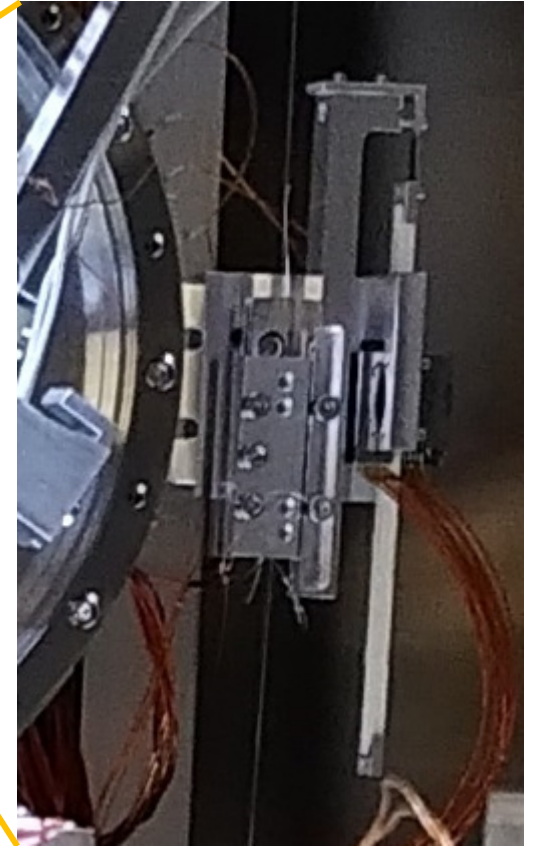
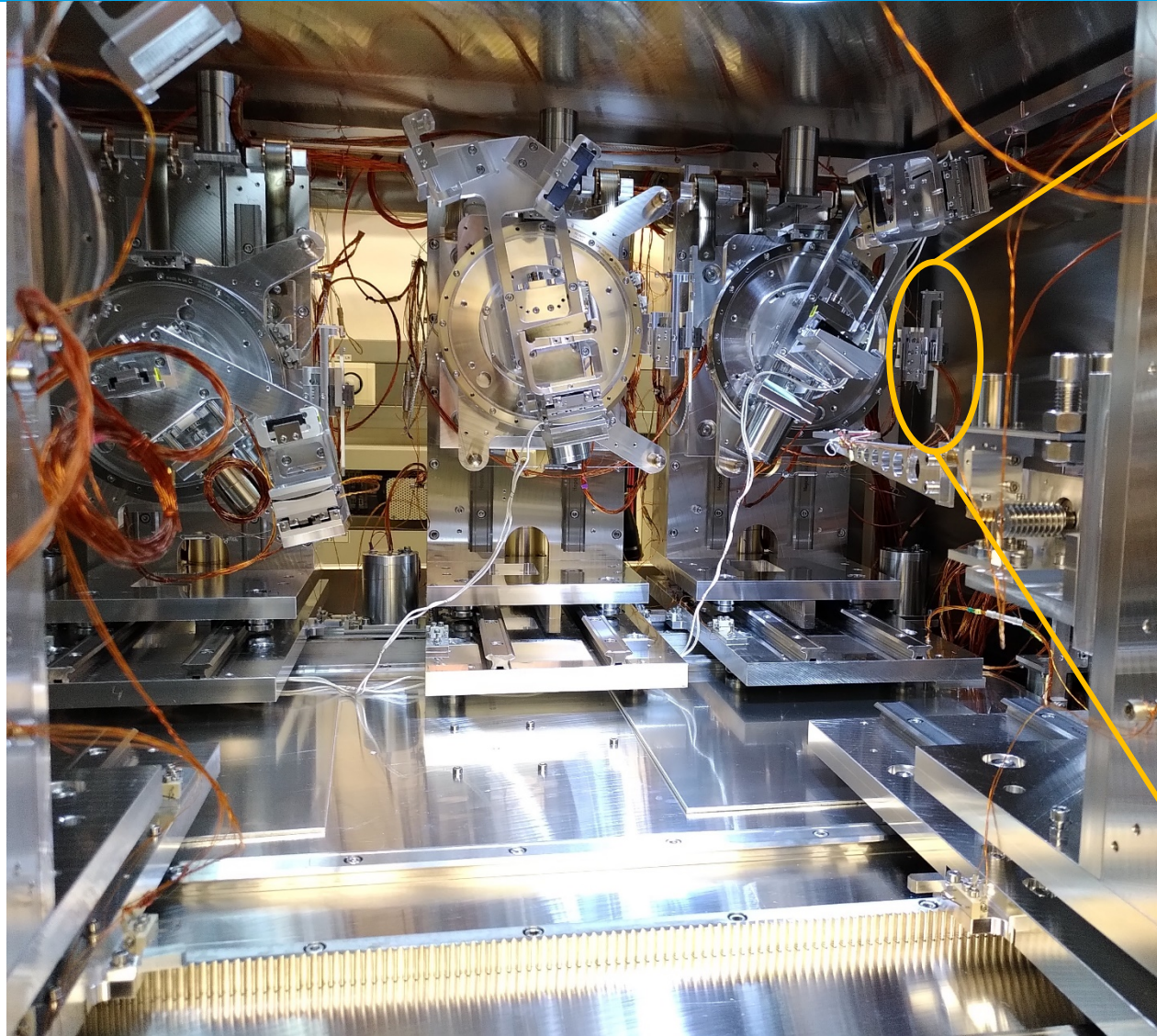


Energy resolution
60 meV
at 2.8 keV

Complete IXS HRM, from March 2021 on



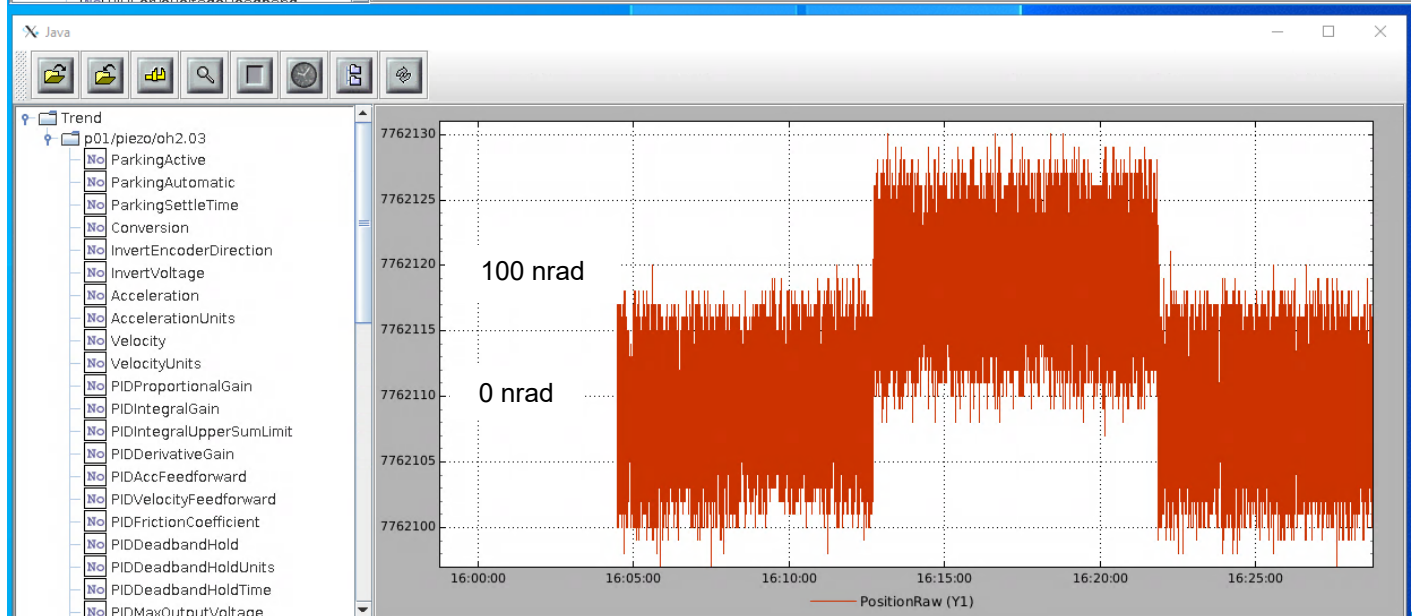
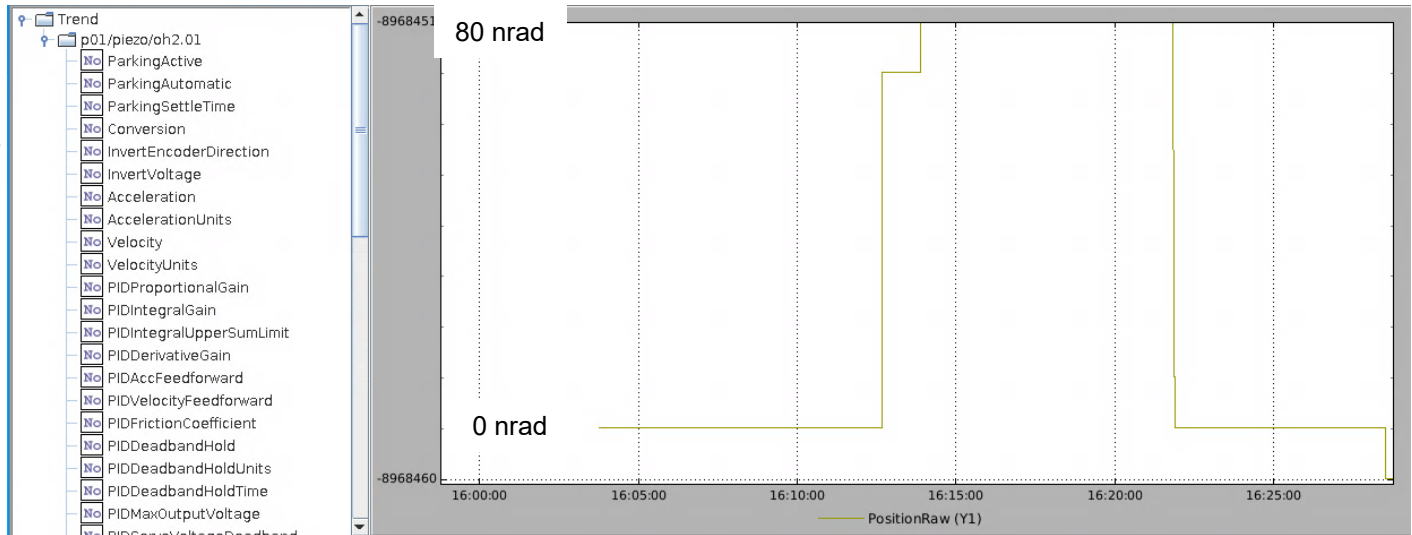
Complete IXS HRM



Resolution and reproducibility

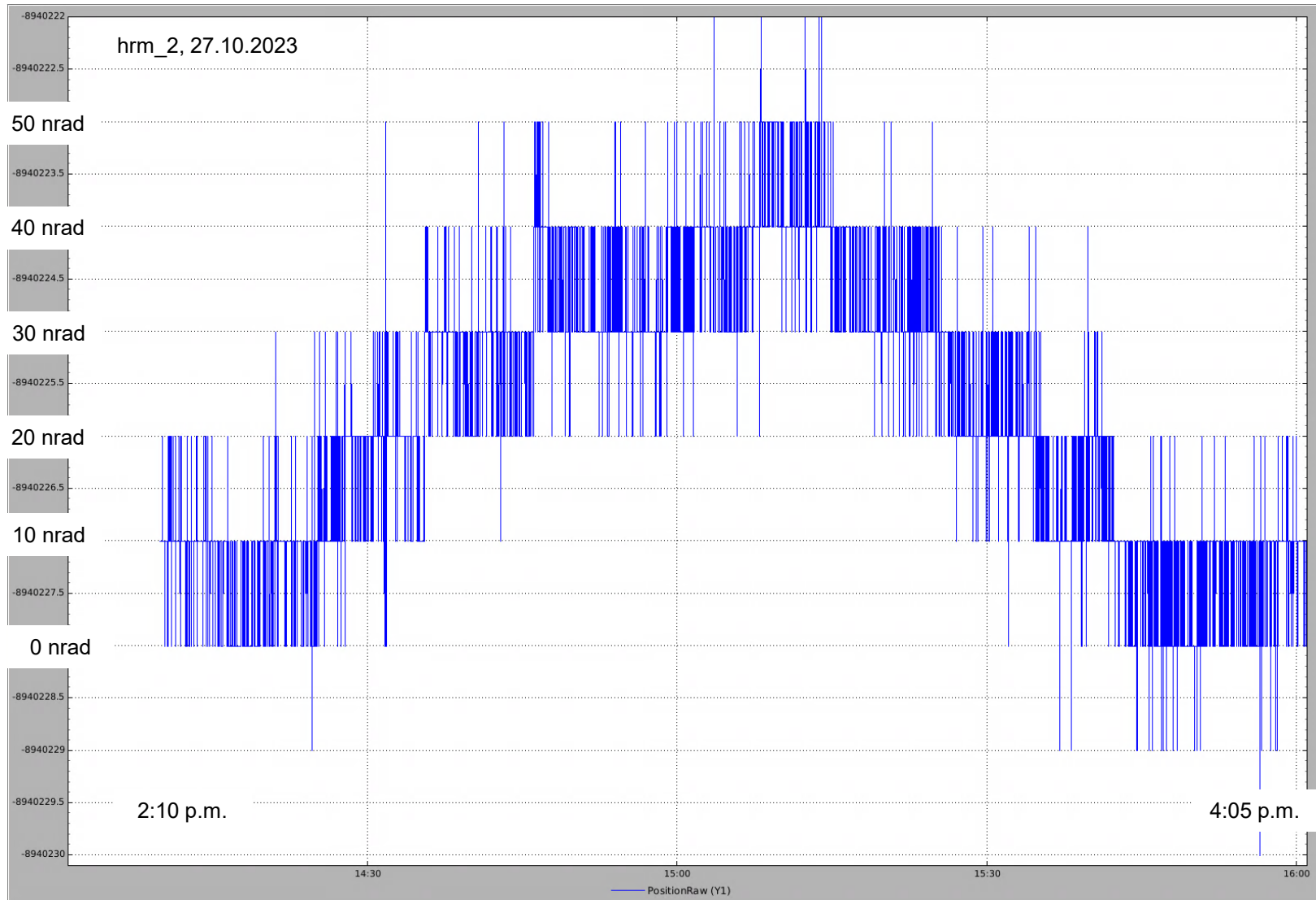
10 nrad = 1 nm
movement

hrm_1 and hrm_3, 27.10.2023



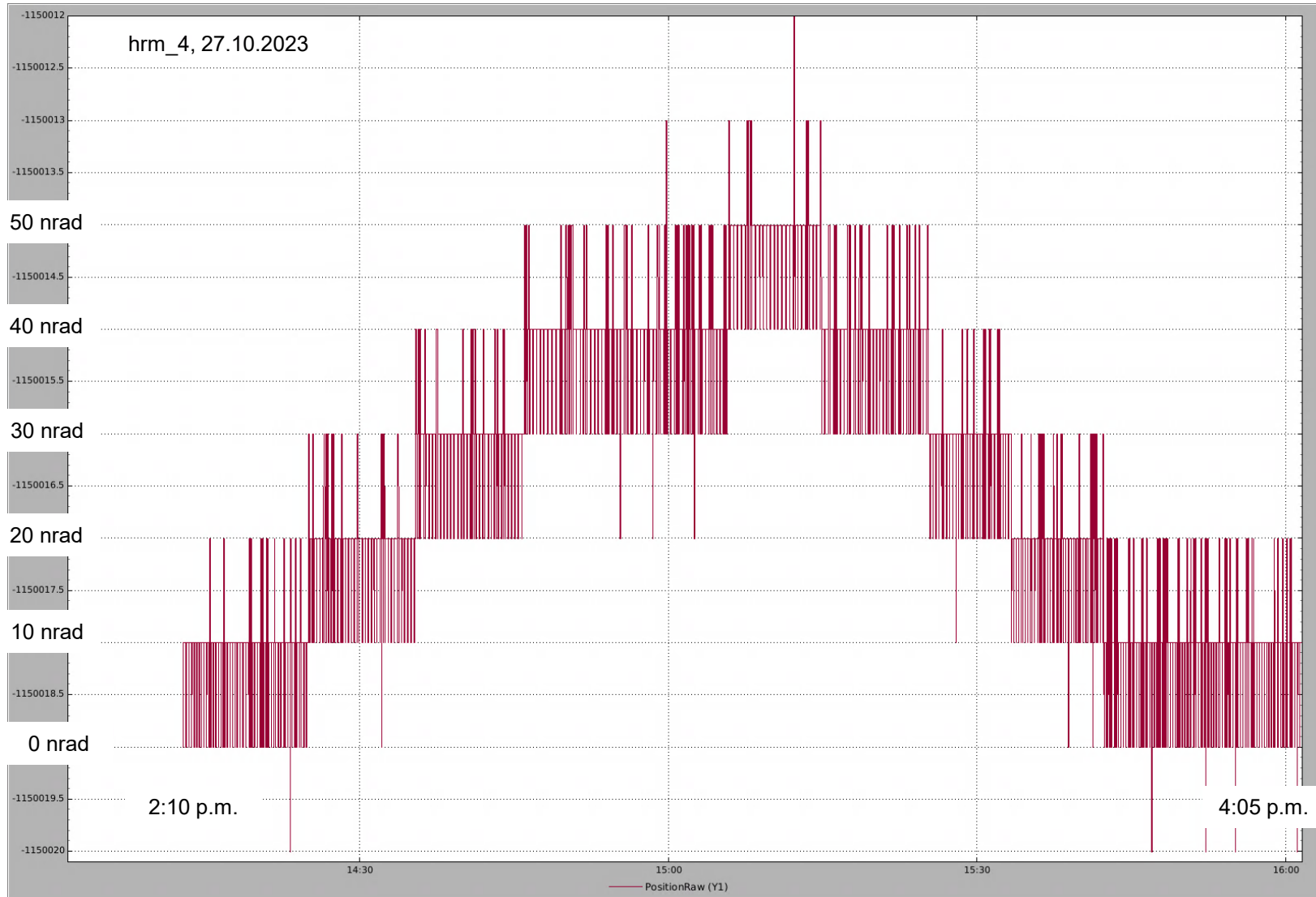
Resolution and reproducibility

10 nrad = 1 nm
movement



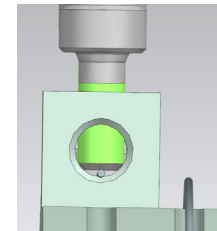
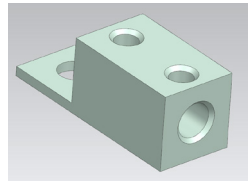
Resolution and reproducibility

10 nrad = 1 nm
movement



Conclusion and Outlook

- High Resolution Monochromator meets all requirements and has shown very good results over the last six years
- The goniometer is a cost-effective in-house solution, ~ 8.000-10.000 € compared to 35.000 € (my work not considered)
- The interpolation cards from NANOS are not any longer available -> test with alternative solution from Piezomotors with a Galil controller
- Eventually the PiezoLEGs will be replaced by a stepper motor driven actuator with 50 nm resolution from VacuumFAB Italy
- Replacement of linear guides in winter shut-down -> $\pm 19.4^\circ$ rotation possible
- Wire clamping has to be improved



Acknowledgements

Max Planck Institute Stuttgart

Director Prof. B. Keimer,
B. Bruha

- Initiator and partner of the project
- Fabricating of almost all Aluminum parts for the goniometers and stages

Desy P01 IXS group

H. Yavas (since Feb. 2018 LCLS Stanford)
H. Gretarsson

S. Mayer

- Scientists
- „Co-Engineer“

Desy Engineering Department

M. Lemke, S. Adler,
C. Martens

- Design/Simulation of the Tank (1,5m³)

Desy Workshop and work planning Dep.

C. Conrad, B. Hager

- Fabrication of the Tank and big Aluminum parts

Desy Electronic Department

D. Lotter, M. Paesler,
F. Reedwisch, J. Voigt

- Support for Cabling

Thank you for your Attention

