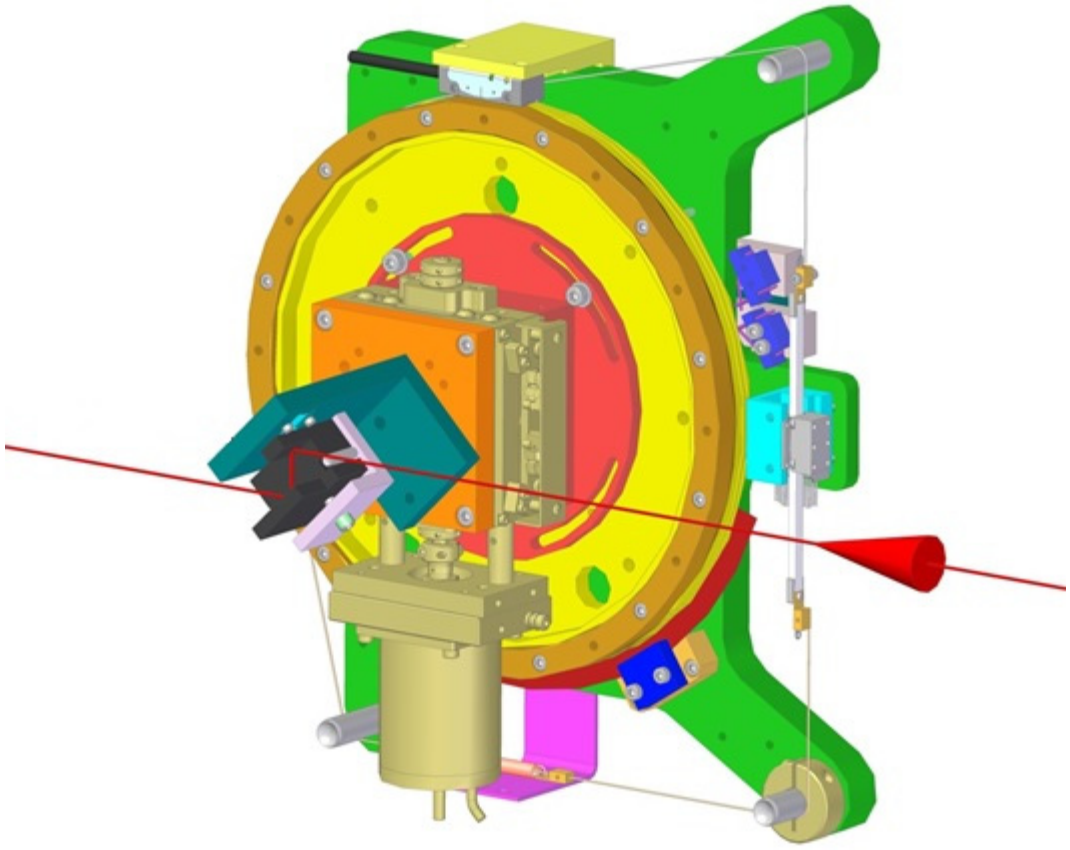
Inhouse Development of a vacuum goniometer with a sub-microradian resolution

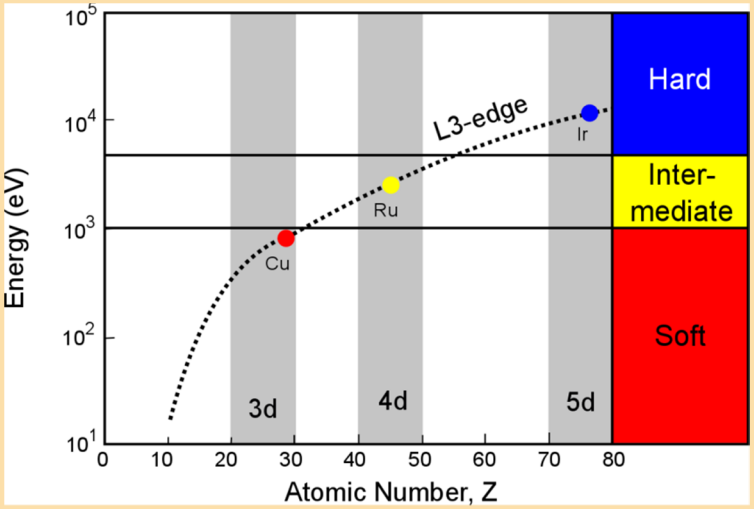


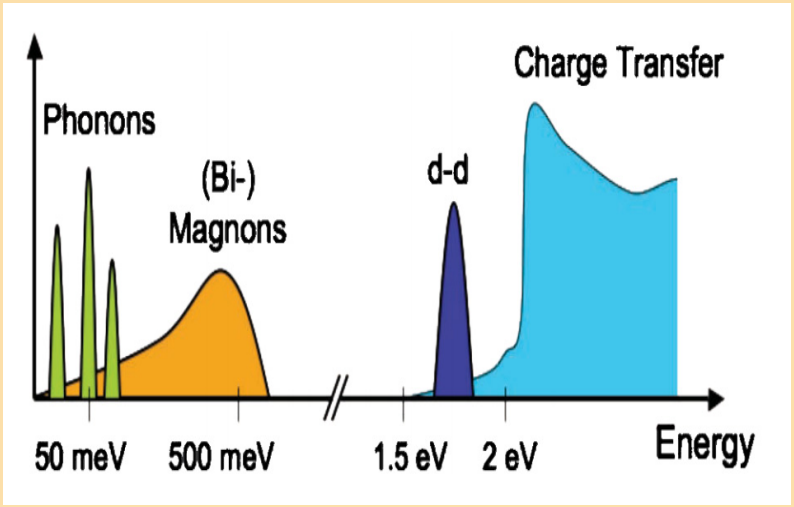
Motivation

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



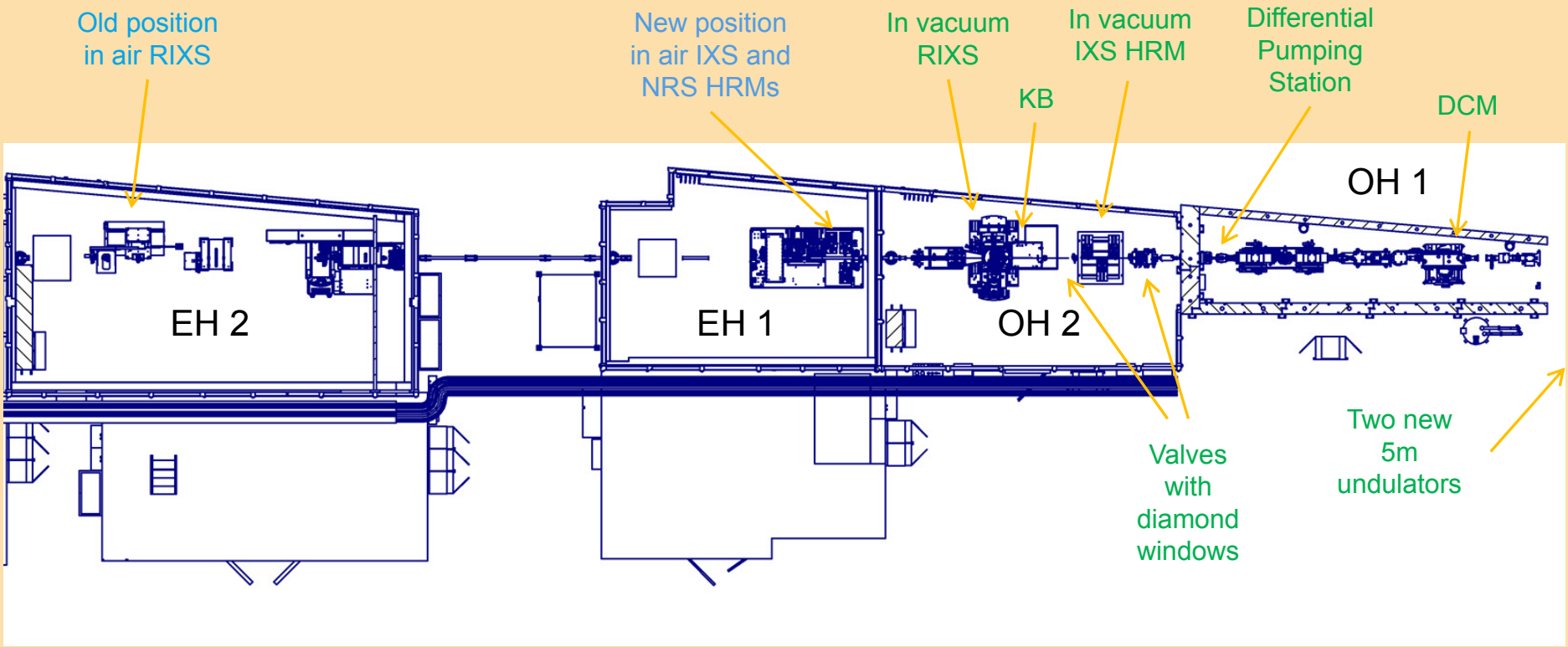


Physical phenomenas that are not understood.
To support theoretical models, as many different variables as possible should be determined by the experiments

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

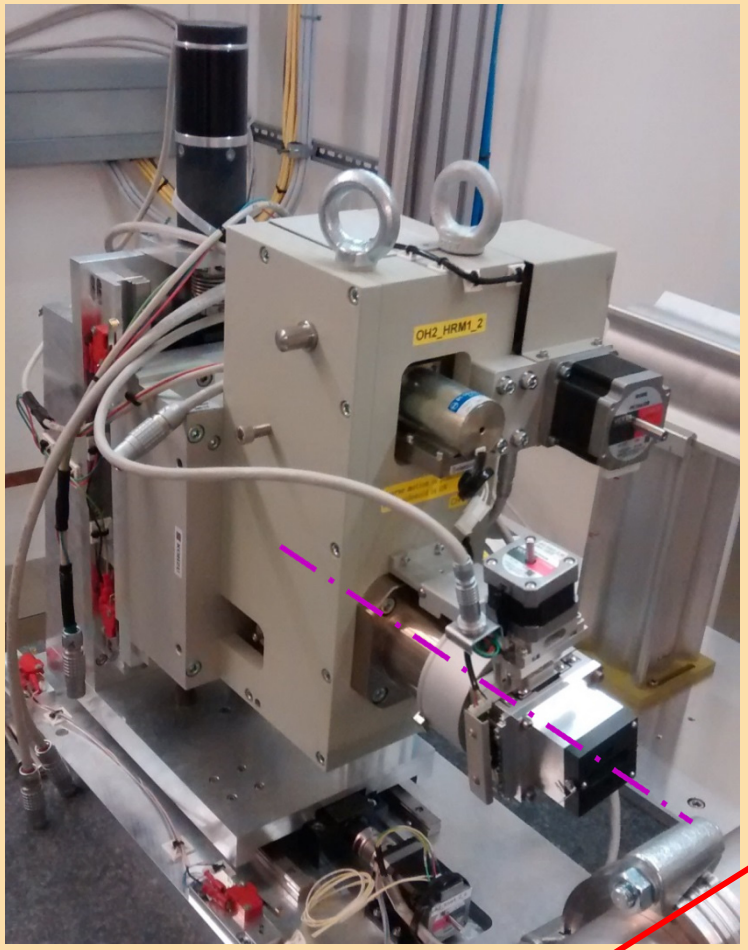
New arrangement of beamline components

Beamline P01 for Inelastic X-Ray Scattering (IXS) and Nuclear Resonant Scattering (NRS) Experiments

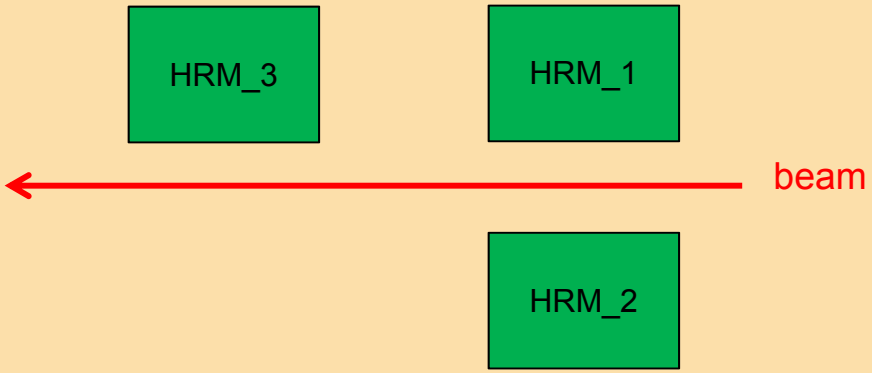


Sample chamber and High Resolution Monochromator have to be put in High Vacuum
Optional no window towards the ring

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 (≠ 10^{-7}mbar). Same for new KTGs

  Costs: modifying 4.300€
  brandnew 30.000€

- Some values of existing Kohzus:

  - wobble 1 arcsec
  - resolution 120nrad (full step of stepper motor)
  - ±2° range fine
  - 360° with clutch and coarse motor

Requirements for the new goniometers

- wobble 1 arcsec (4,8µrad) within +-5° rotation
- Possible load of 6kg (for bigger crystal setups)

Precise and robust bearing

- Motorized Range of +-20°, manually +-90°
- Angular resolution of 0,5 microrad

Precise actuator with long travel range

- Vacuum compatible to $5x10^{-7}$mbar

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

Original design by
Hans-Bernhard Peters
from ZM1-DESY

Housing
stainless steel
Ø38mm
Length 120mm

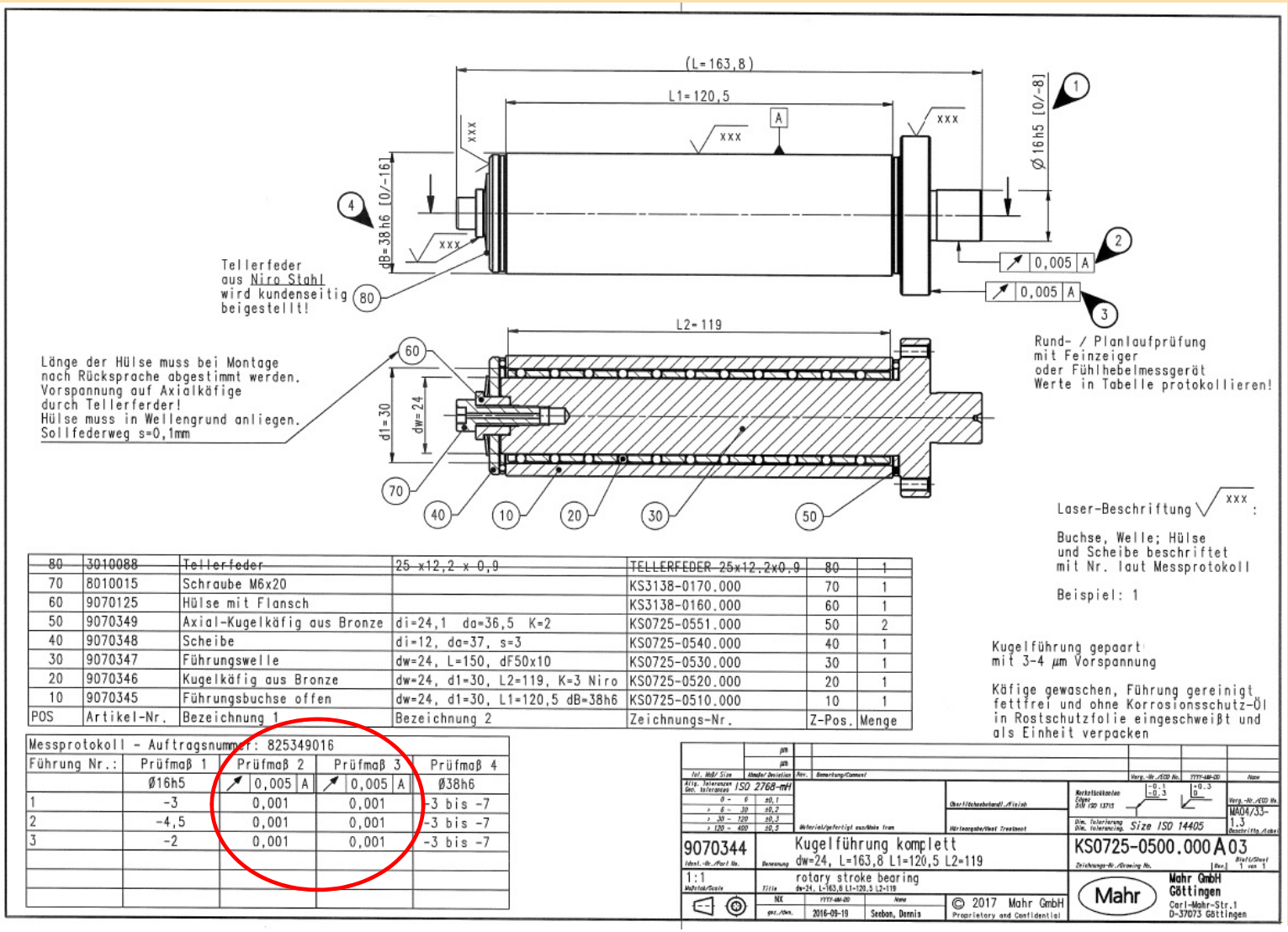
Ball Cage, bronze

Axial Bearing, bronze

Balls
stainless steel, Ø3mm

Shaft
stainless steel, Ø16mm

High Precision Mahr Bearing, Measurement Record



POS	Artikel-Nr.	Bezeichnung 1	Bezeichnung 2	Zeichnungs-Nr.	Z-Pos.	Menge
~~80~~	~~3010088~~	~~Tellerfeder~~	~~25 x12,2 x 0,9~~	~~TELLERFEDER 25x12.2x0.9~~	~~80~~	~~1~~
70	8010015	Schraube M6x20		KS3138-0170.000	70	1
60	9070125	Hülse mit Flansch		KS3138-0160.000	60	1
50	9070349	Axial-Kugelkäfig aus Bronze	di=24,1 da=36,5 K=2	KS0725-0551.000	50	2
40	9070348	Scheibe	di=12, da=37, s=3	KS0725-0540.000	40	1
30	9070347	Führungswelle	dw=24, L=150, dF50x10	KS0725-0530.000	30	1
20	9070346	Kugelkäfig aus Bronze	dw=24, d1=30, L2=119, K=3 Niro	KS0725-0520.000	20	1
10	9070345	Führungsbuchse offen	dw=24, d1=30, L1=120,5 dB=38h6	KS0725-0510.000	10	1

Messprotokoll - Auftragsnummer: 825349016

Führung Nr.:	Prüfmaß 1	Prüfmaß 2	Prüfmaß 3	Prüfmaß 4
	Ø16h5	0,005 A	0,005 A	Ø38h6
1	-3	0,001	0,001	-3 bis -7
2	-4,5	0,001	0,001	-3 bis -7
3	-2	0,001	0,001	-3 bis -7

9070344	Kugelführung komplett dw=24, L=163,8 L1=120,5 L2=119	KS0725-0500.000 A 03
1:1	rotary stroke bearing dw=24, L=163,8 L1=120,5 L2=119	Mahr GmbH Göttingen Carl-Mahr-Str.1 D-37073 Göttingen

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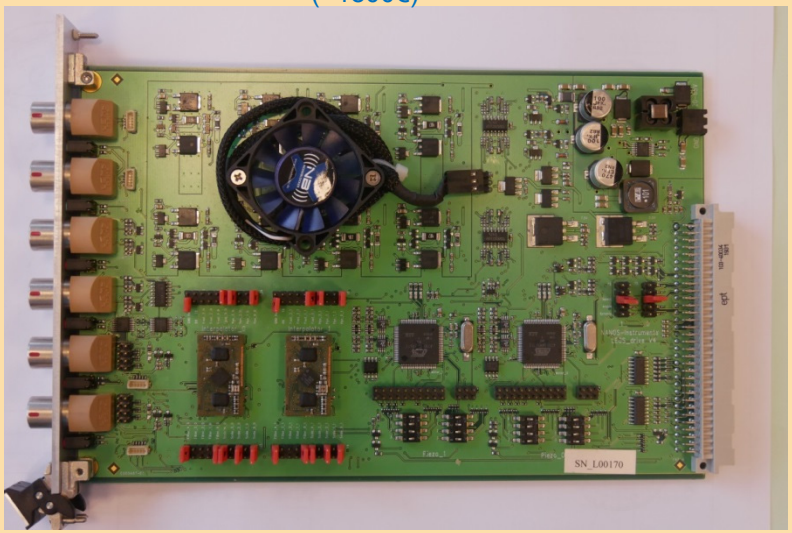
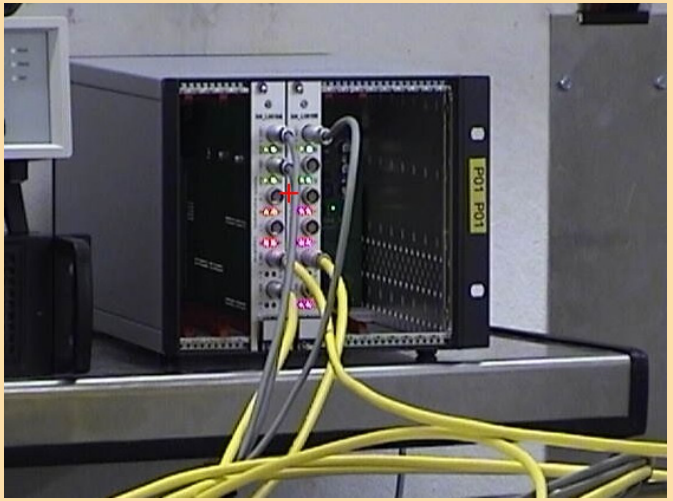
PiezoLEG and NANOS piezo driver and interpolation card

NANOS interpolation and driver card for 2 channels
Interpolation of 1VSS up to 100.000
-> 0,2nm with a 20µm scale
(~1800€)





Piezo driven goniometer

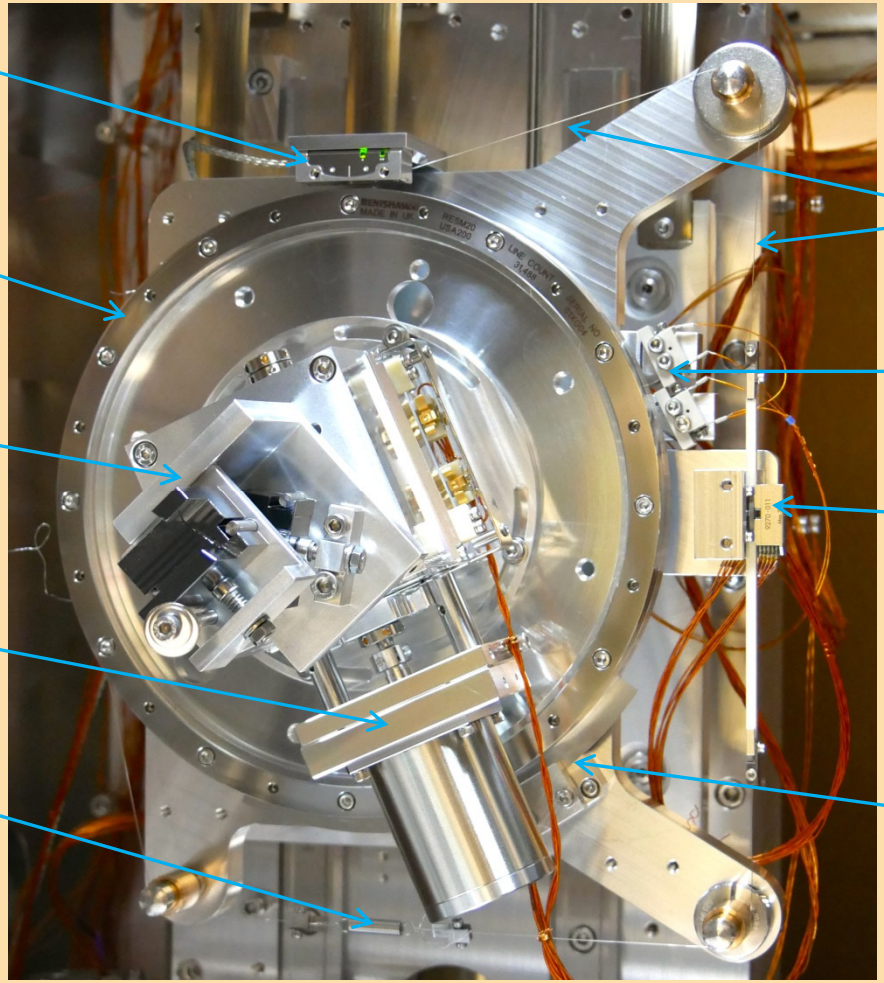
Encoder
(700€)

Encoder wheel
Ø 200mm
20µm scale
(700€)

Crystal holder
for 2 channel cuts

Kohzu tilt stage
(5000€)

Spring



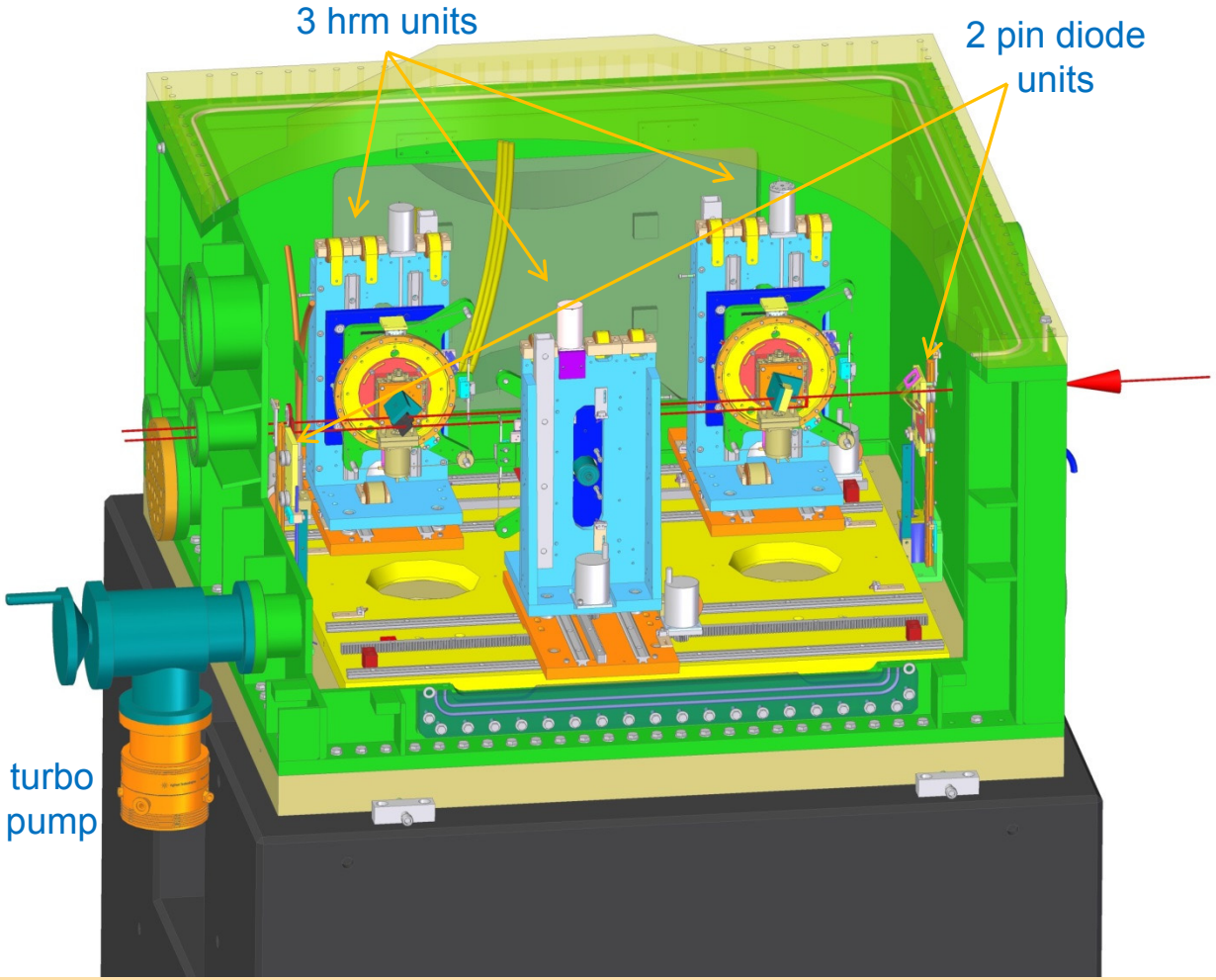
Wire
Ø 0,3mm

Limit
Switches
Inhouse Design S.
Mayer

Piezo LEGS
with rod
110mm length
(1600€)

Manual brake
(for service)

Complete IXS HRM



Tank

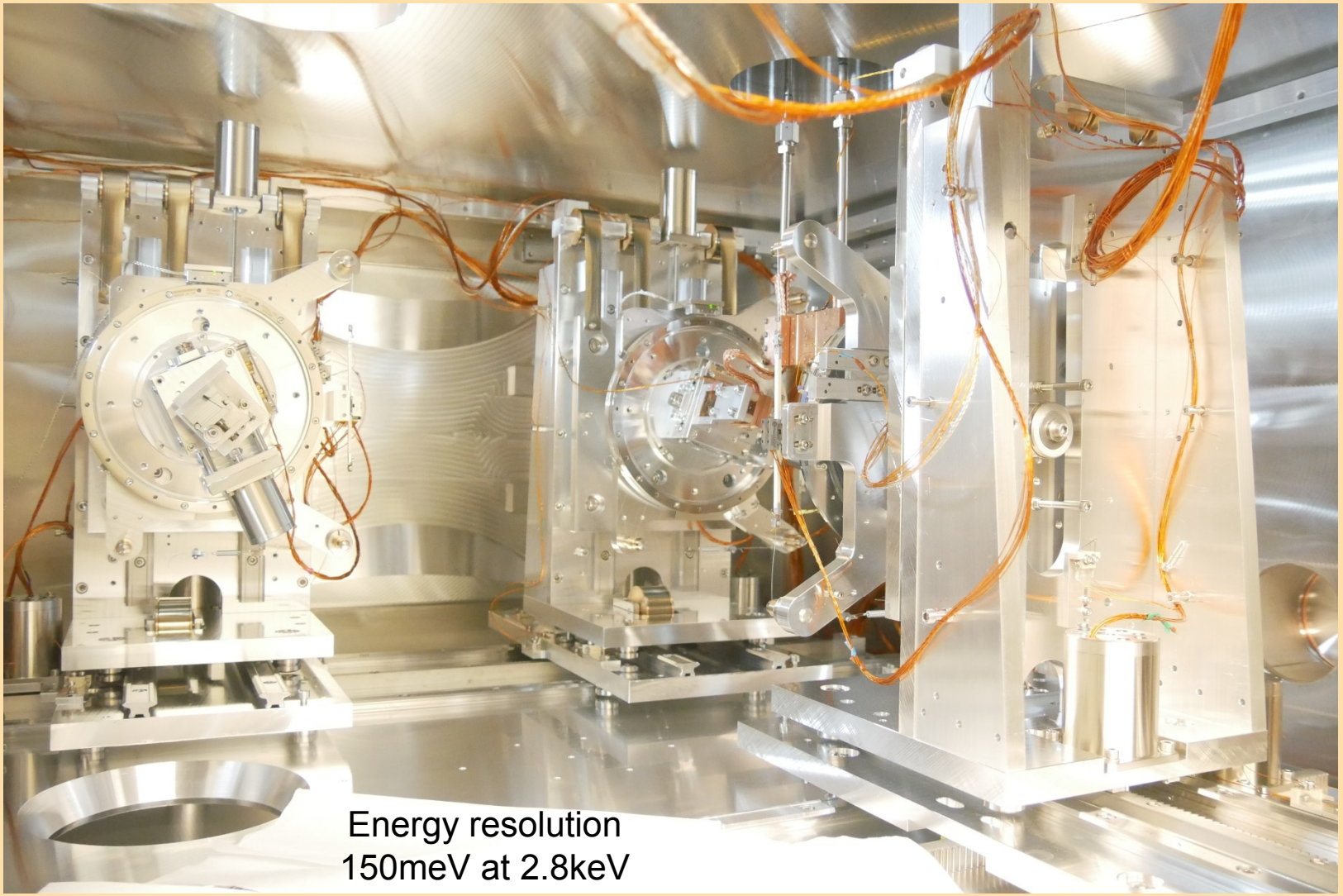
1,4m x 1,3m x 0,8m = 1,45m^3

Body stainless steel
Top / Bottom Aluminum

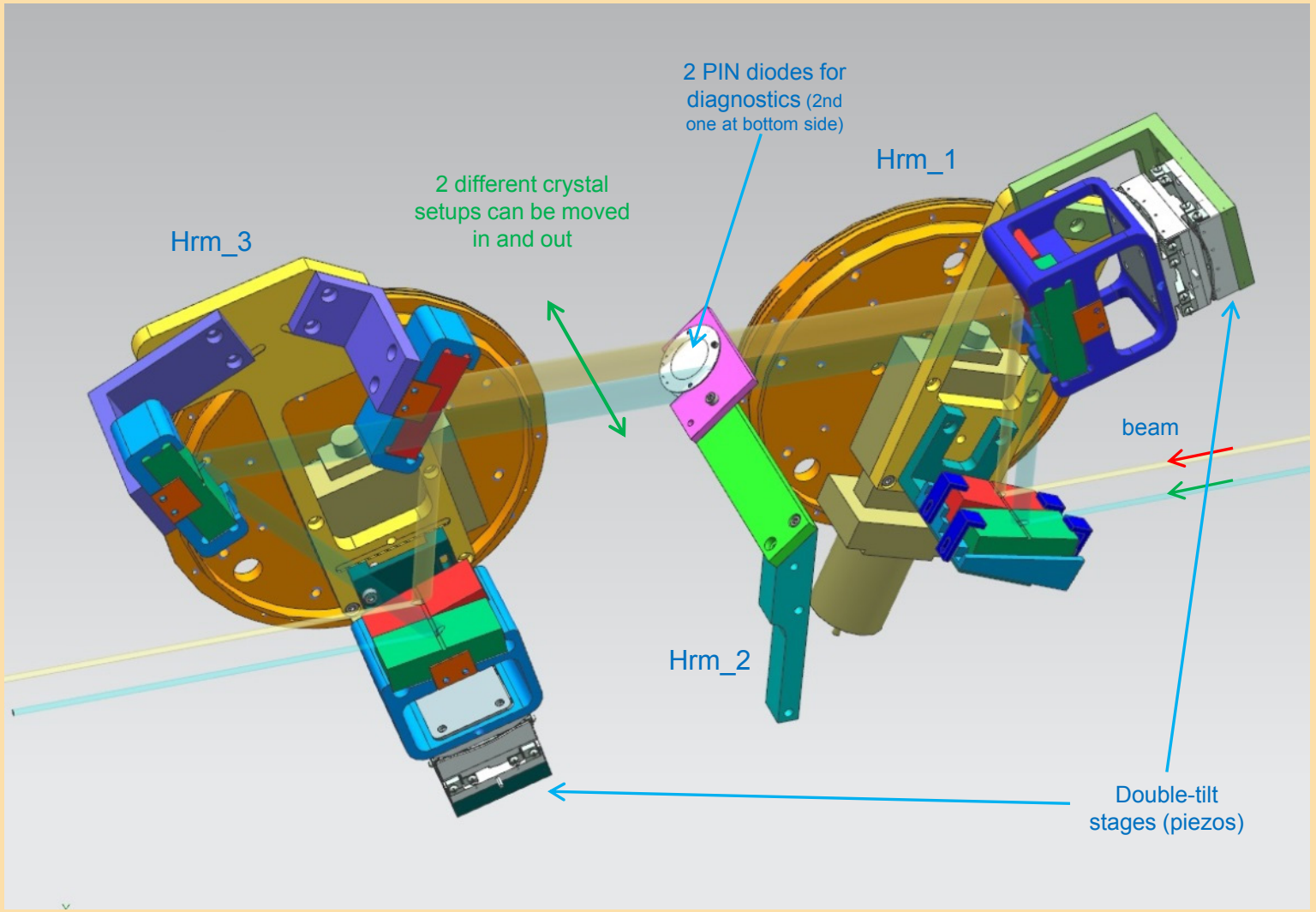
Vacuum

3,6 x 10-7mbar with two 300l Getterpumps
1,5 x 10-6mbar with one 300l Turbopump

Complete IXS HRM



New setup, 2 sets, each with 4 crystals



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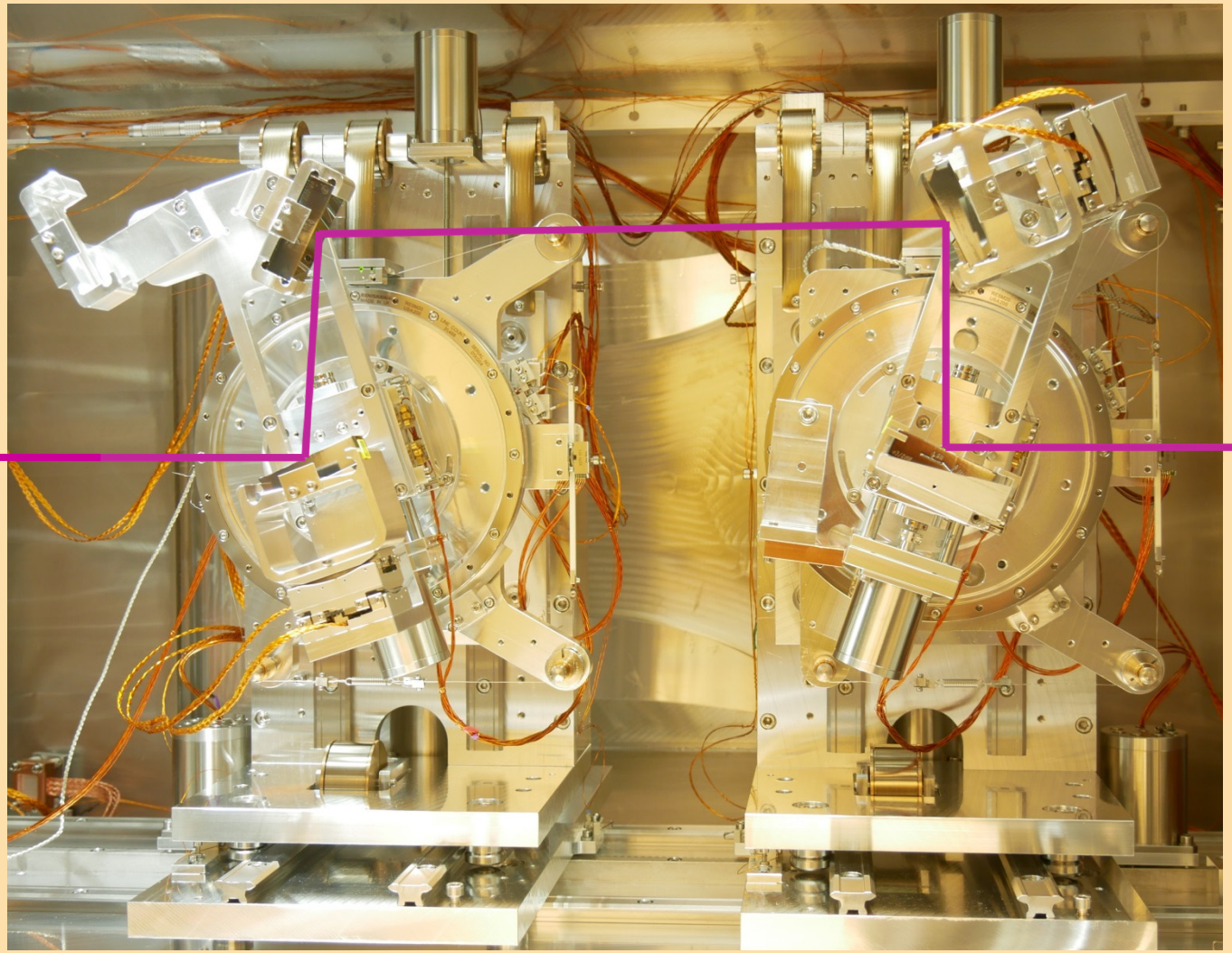
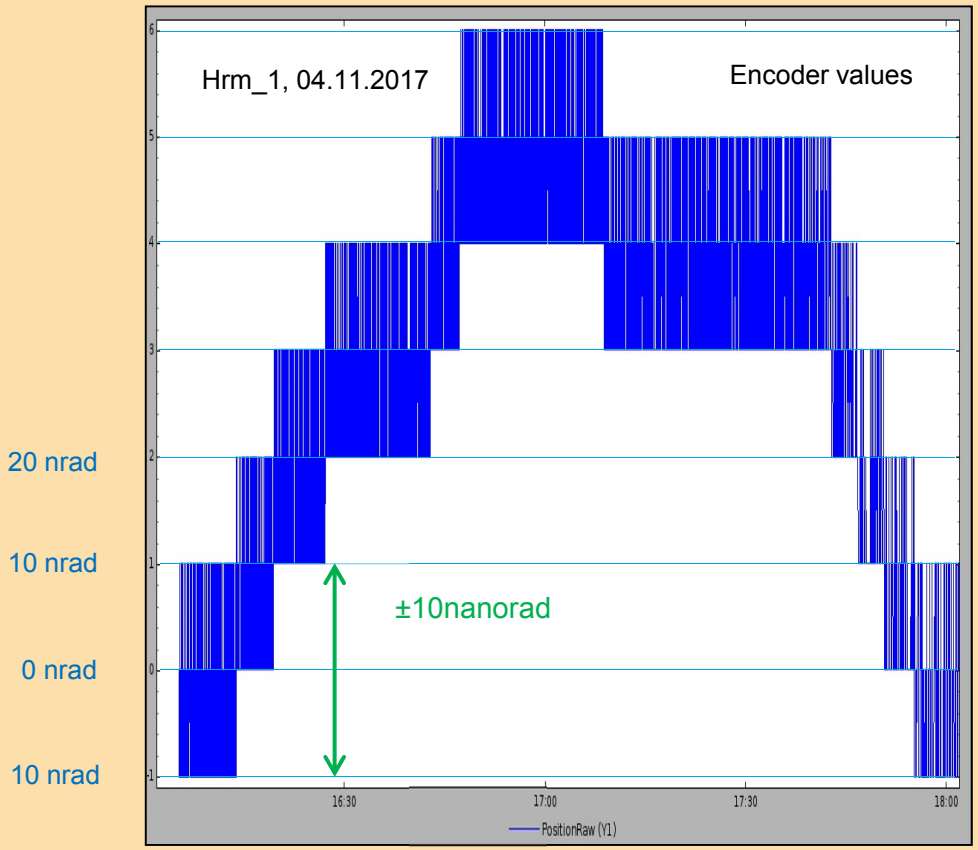


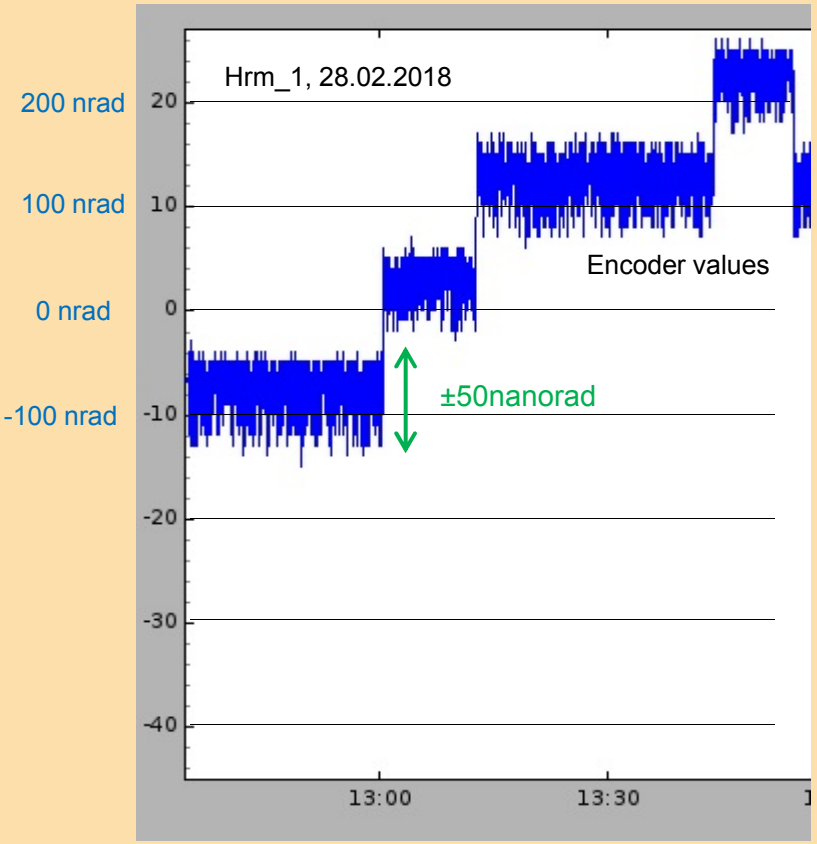
Energy resolution 100meV at 2.8keV

Reproducibility and Jitter

Reproducible steps much better than 500nrad (required)
but Jitter and resolution of goniometers changed

Hrm1 & 3 Jitter got worse after 4 months

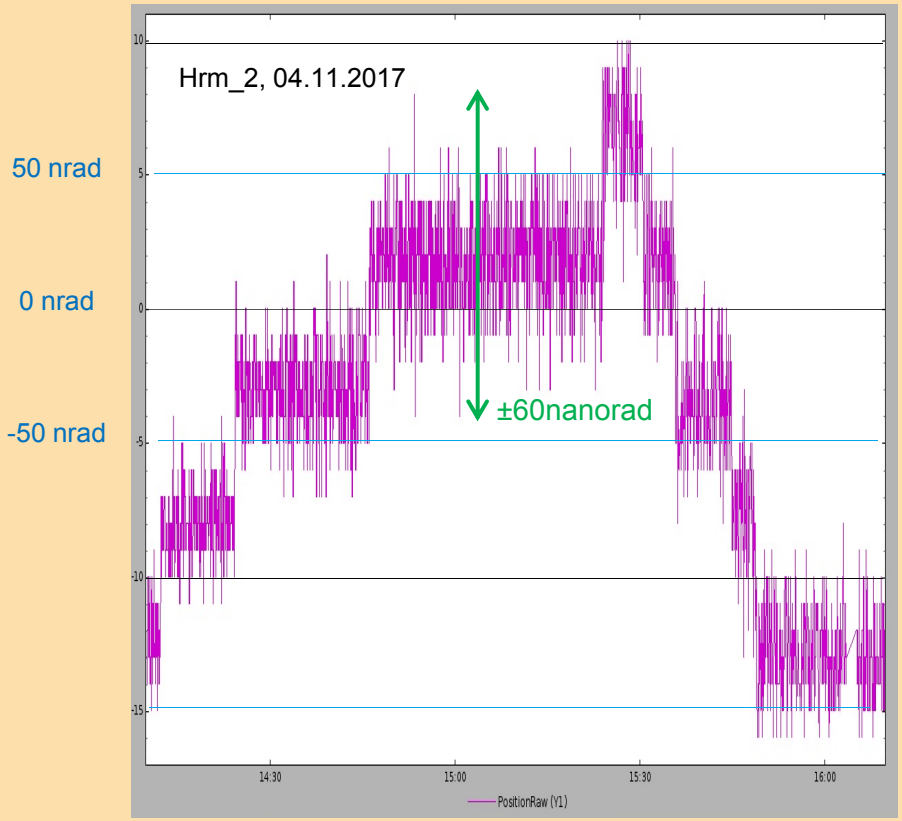


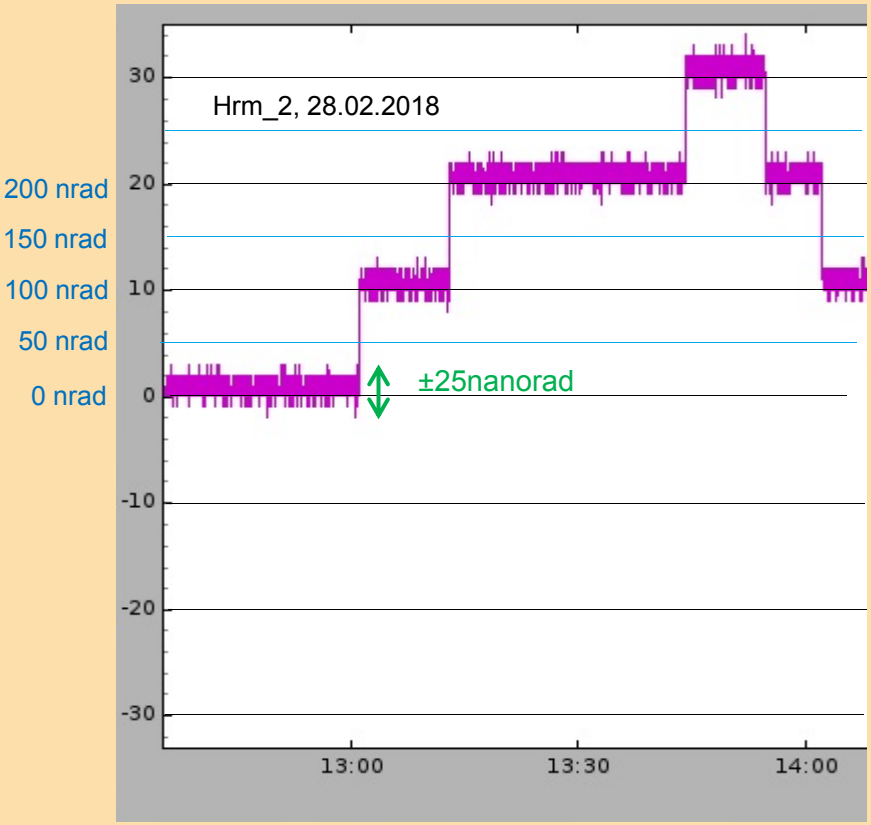


Reproducibility and Jitter

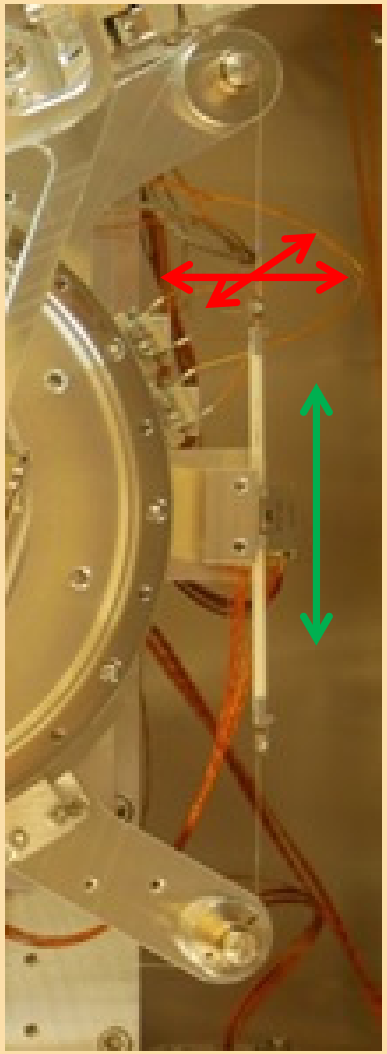
Reproducible steps much better than 500nrad (required)
but Jitter and resolution of goniometers changed

Hrm_2 Jitter got better after 4 months





Possible reason for change of resolution and Jitter



The PiezoLEG does not like any forces perpendicular to the moving direction

-> add a linear guidance for the wire

Conclusion and Outlook

- Very simple concept shows very good results over the last 12 months
  (installation and first use in June 2017)

  -> scientists are happy

- The goniometer is a cost-saving in house solution,
  ~ 8.000-10.000€ compaired to 30.000€ (my work not considered)

- The three different setups do have different Jitters / resolutions
  and both changes over time

  – > PiezoLEG must be decoupled from the wire (urgent)

  – > I should have built a fourth setup to do tests in general

Acknoledgements

Max Planck Institute Stuttgart

Director Prof. B. Keimer, H. Gretarsson
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)
S. Mayer

- Scientist
- „Co-Engineer“

Desy Engineering Department

M. Lemke, S. Adler,
C. Martens

- Design/Simulation of the Tank (1,5m^3)

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

In Vacuum Goniometer

Thank you for your Attention