Workshop on „Parallel Computing for Data Acquisition and Online Monitoring“

Computational Challenges for Microtomography using Synchrotron Radiation at PETRA III

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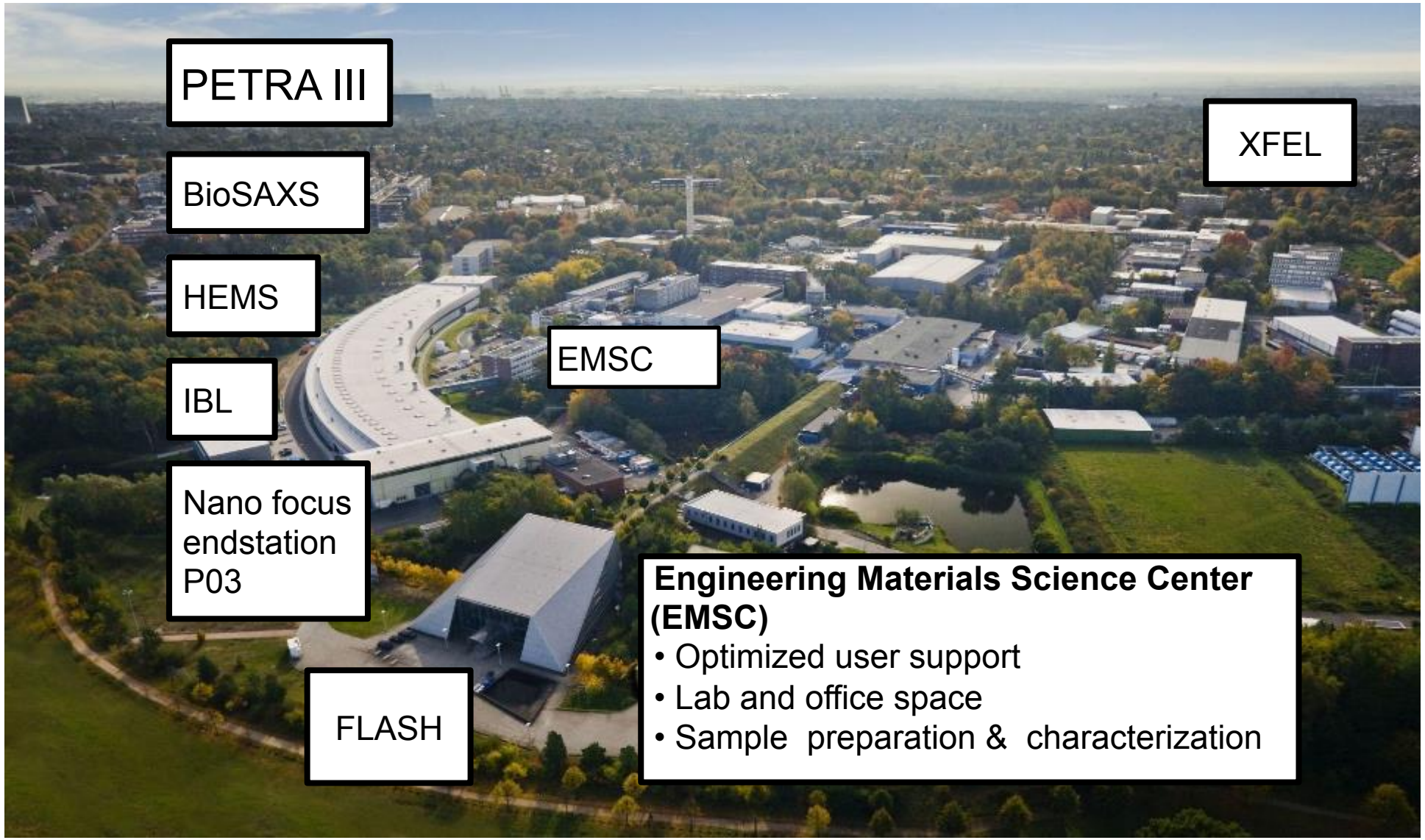
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

GEMS
German Engineering Materials Science Centre

HZG outstation at DESY

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



GEMS
German Engineering Materials Science Centre

Imaging Beamline P05 Layout

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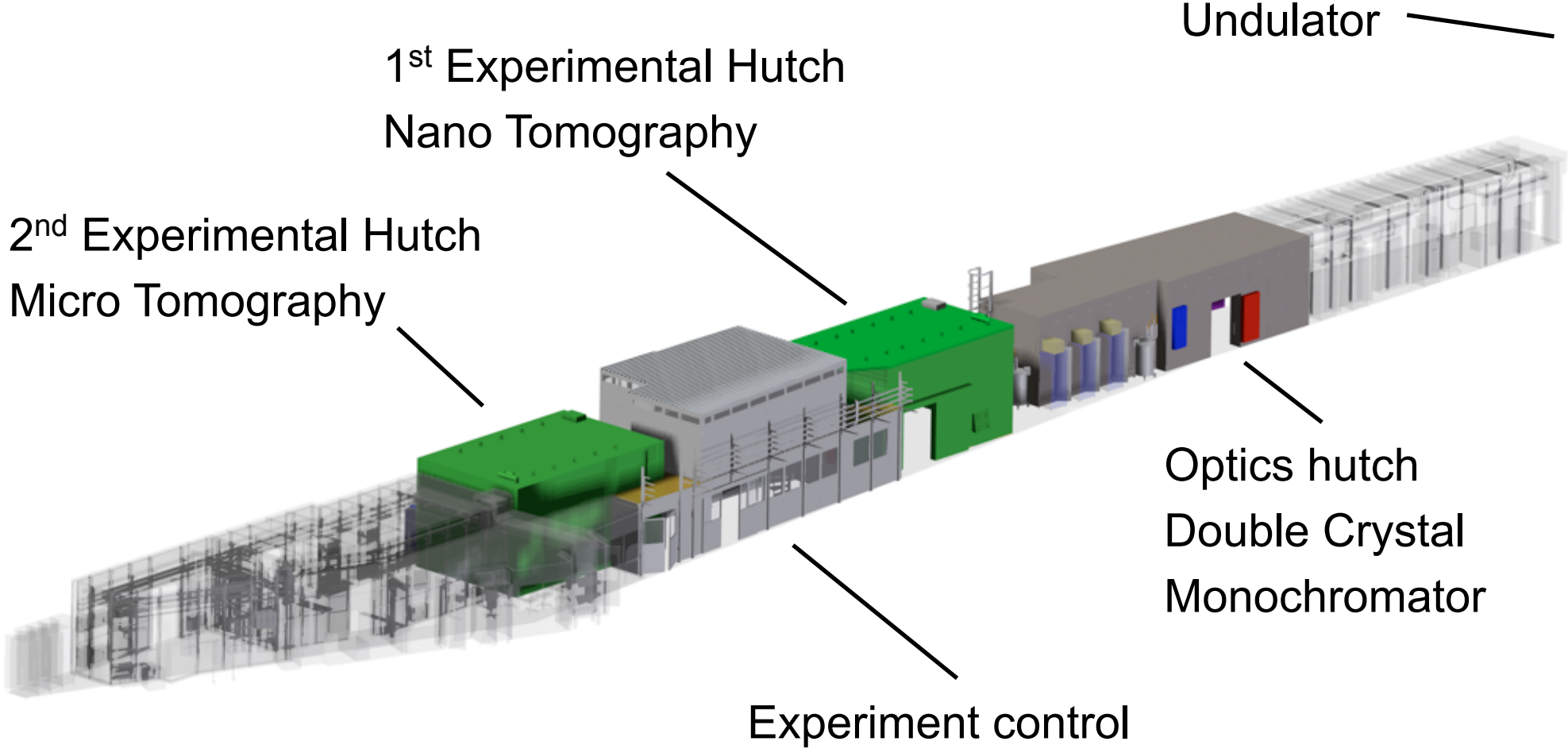

High-energy SRμCT at PETRA III / DESY

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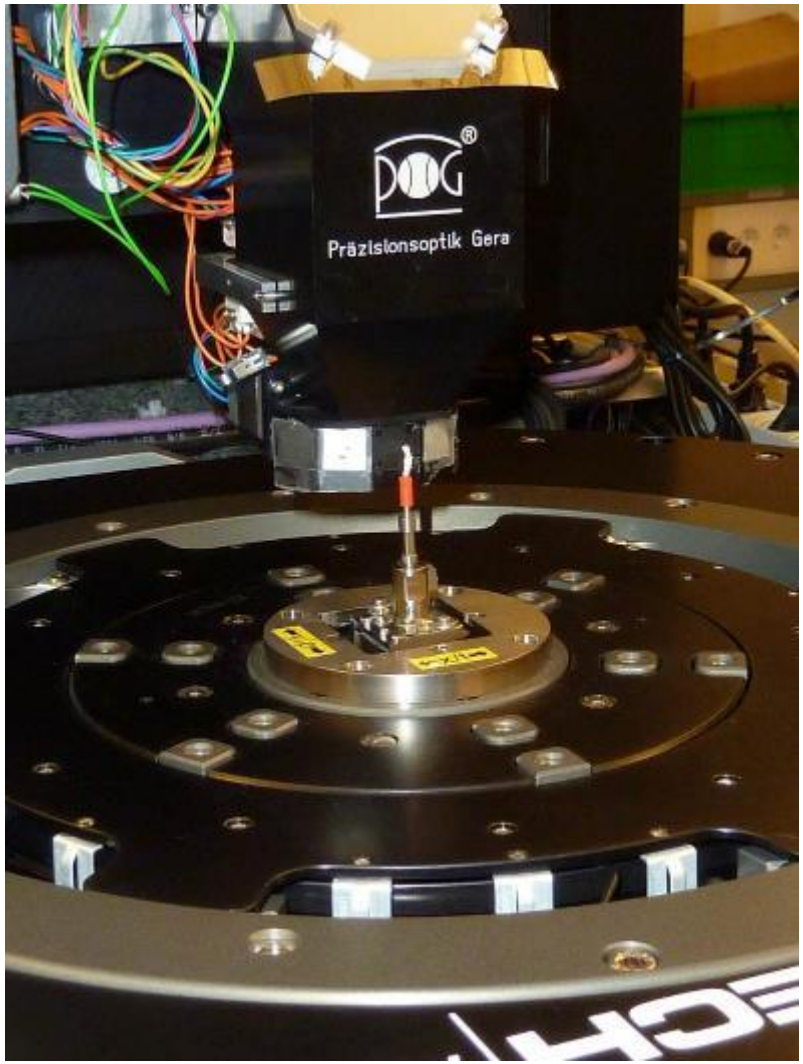
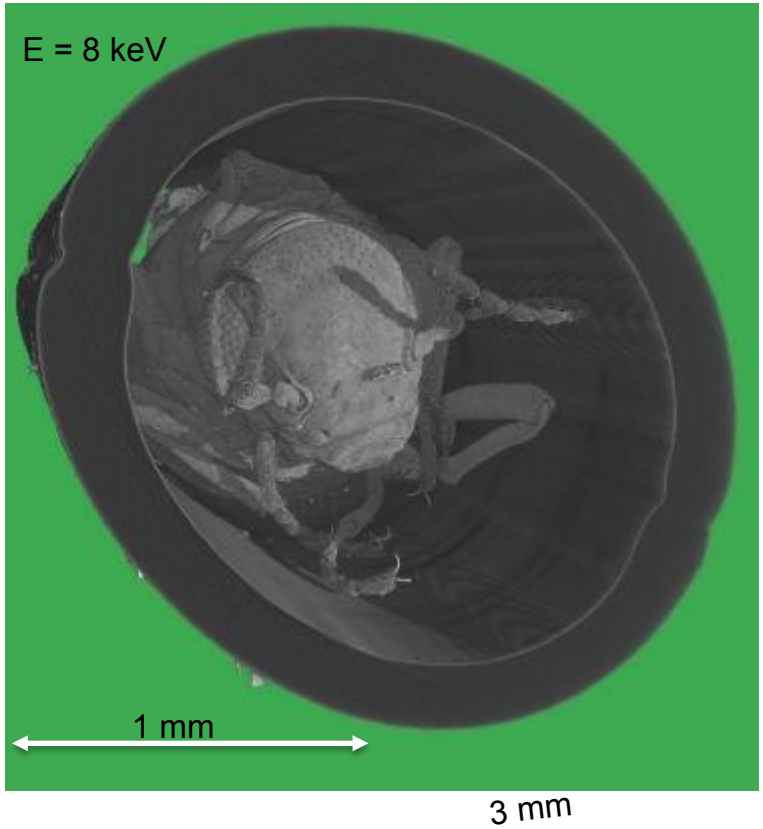
SRμCT at beamline P07 (HEMS)

Sample: *Vaceletia nov. sp.* (Porifera)

Sample diameter: 2.5 mm



SRμCT Experiment at P05



Anatomy of Moss Flea revealed

Sample: *Caurinus sp.* (Moss Flea), freeze dried.

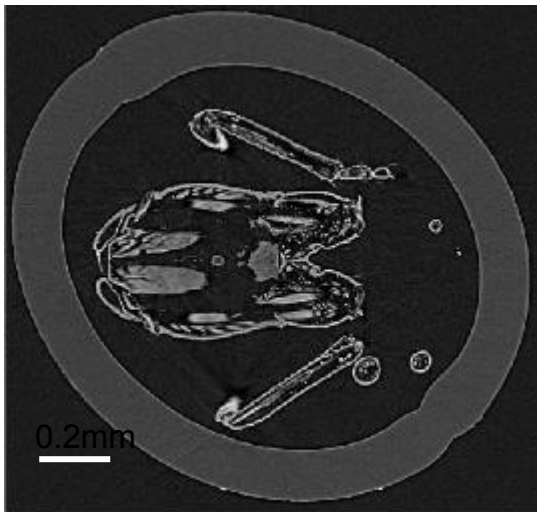
Sample size: 2 mm x 1 mm

Photon energy: 8 keV

Pixel size: 1.22 μm

Spatial resolution: 1.22 μm

Reconstructed volume: 1.25 x 1.14 x 2.33 mm³



In cooperation with:

F. Friedrich,
Biocentrum Grindel & Zoological Museum,
University of Hamburg

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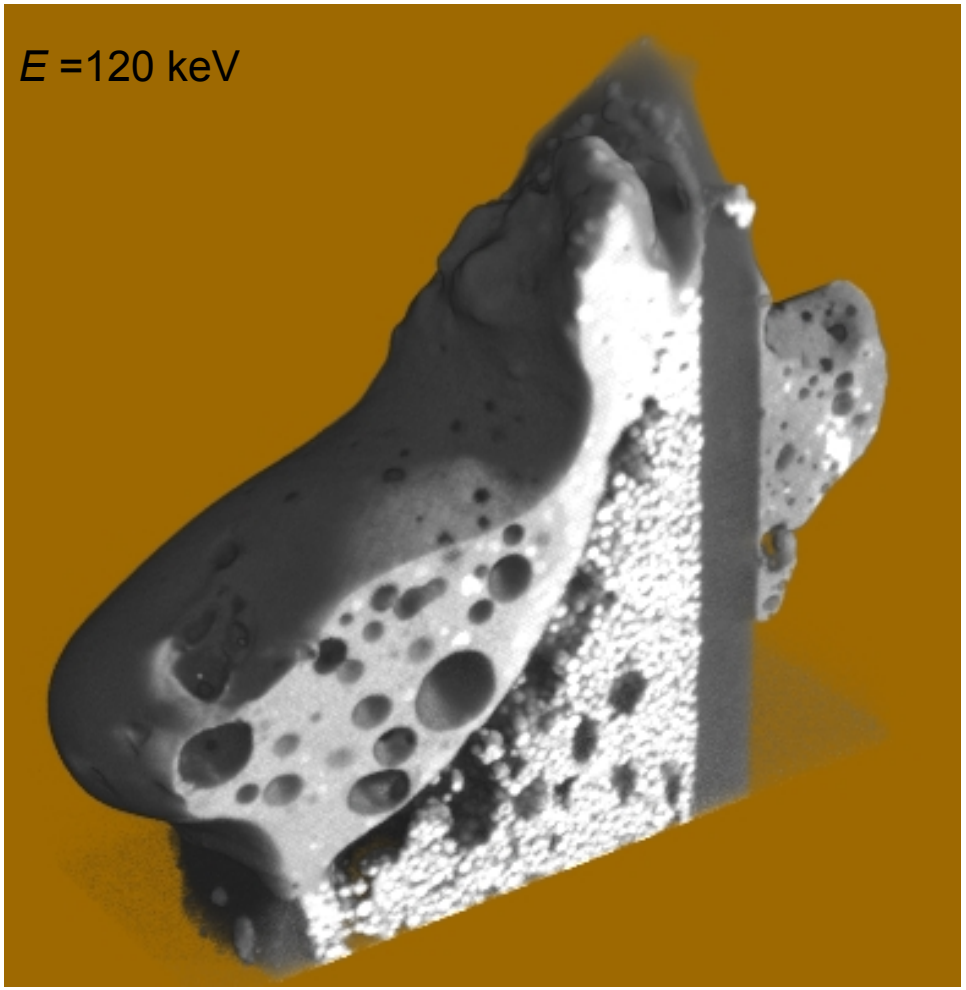
Understanding of the twin wire arc spraying process



SRµCT at beamline P07 (HEMS)

Sample: cored wire for twin wire arc spraying

Sample size: 1.5 mm in diameter

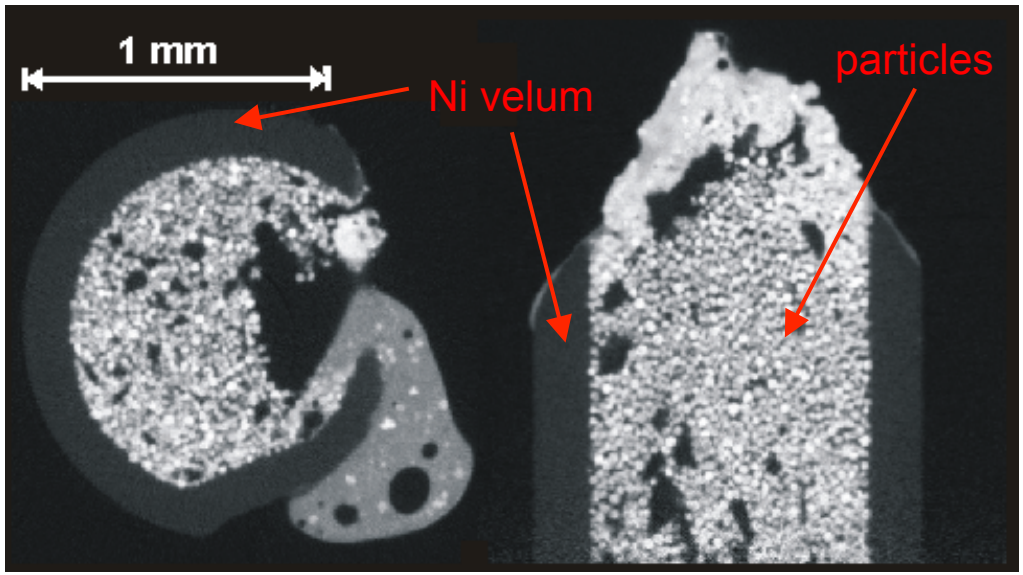
Particle size: WC/Co (25 – 45 µm)

Photon energy: 120 keV

Pixel size: 2.4 µm

Spatial resolution: 5 µm

Reconstructed volume: 2.0 x 2.1 x 2.3 mm³



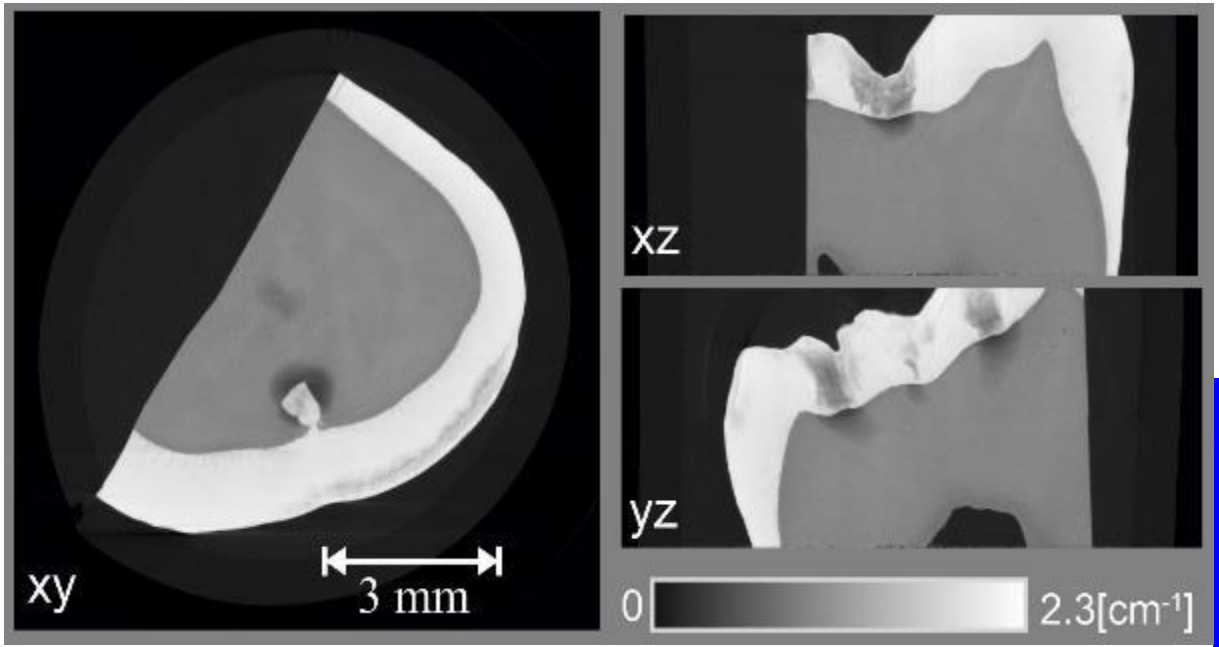
In cooperation with:

technische universität dortmund

Lehrstuhl für Werkstofftechnologie

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Demineralization in human tooth samples



In cooperation with

I. Dziadowiec, B. Müller:
University of Basel, Switzerland

SRμCT at beamline P07 (HEMS)

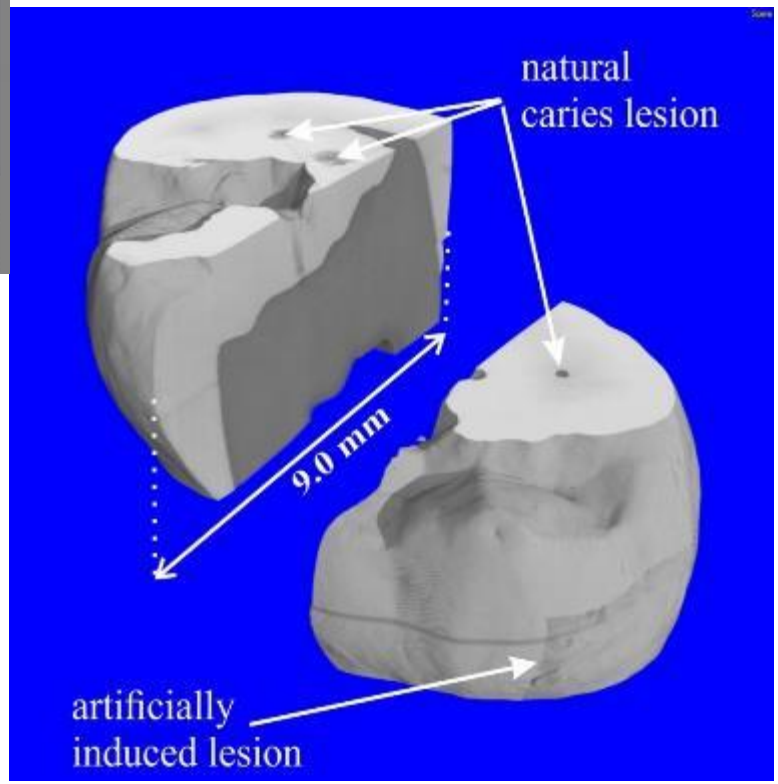
Sample: human tooth

Sample size: 10 mm in diameter

Photon energy: 45 keV

Pixel size: 9.6 μm

Reconstructed volume: 13.2 x 13.2 x 5.2 mm³



Sample pre-characterization

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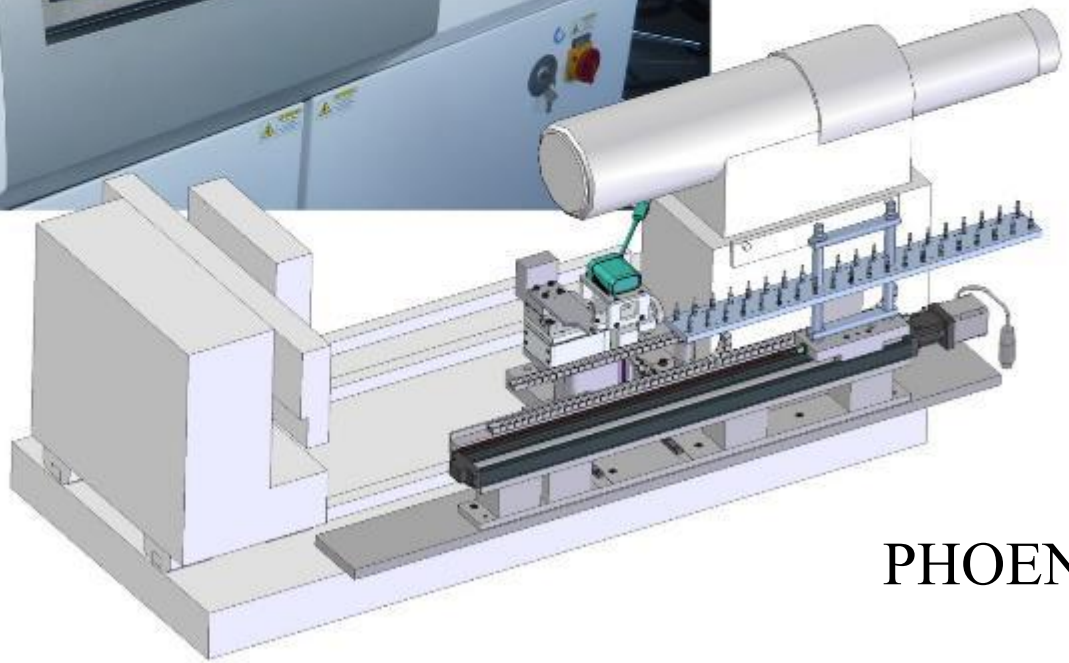
- X-ray inspection
- automatic sample changer
- automatic scanning of 18 samples
- information used for defining region of interest, scan parameter, and area for reconstruction

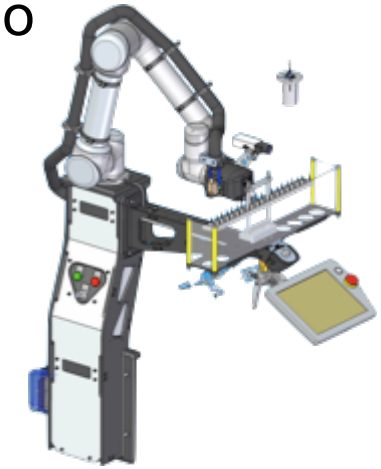


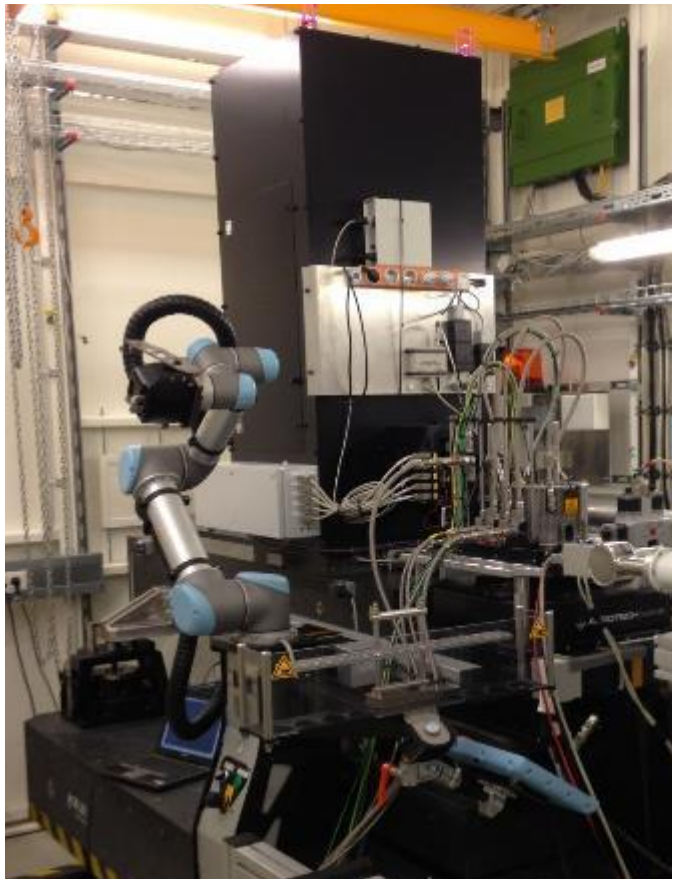
Scripting-Software
for the NANOTOM
in cooperation with
PHOENIX X-ray, Germany

Sample Changer

Sample Changer:

- Sample changer Robot arm (Universal Robots UR5)
- Integration into setup in-house by HZG Technikum
- Space for 20 samples
- Standardized sample holder with data matrix
- Implemented into Tango

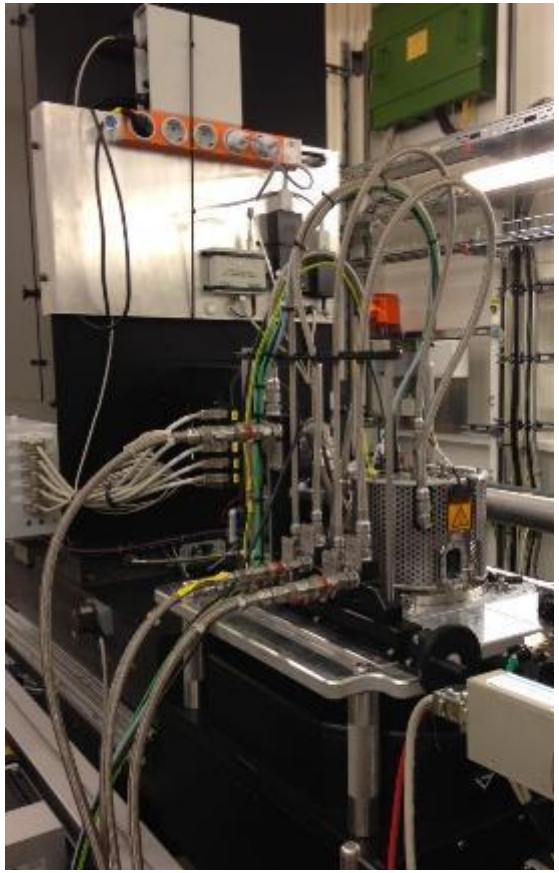


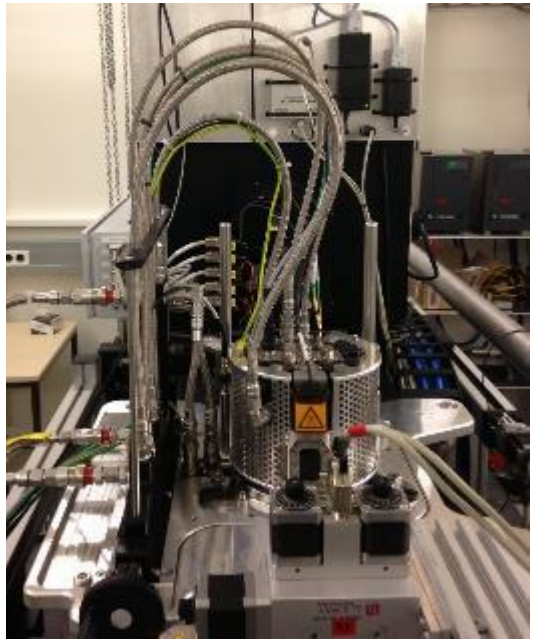


Sample environments

Furnace:

- *In-situ* furnace designed specifically for µCT setup
- Design and construction by HZG Technikum
- Max. temperature 800 C
- Fully remote controlled (via Tango)
- Gas inlet and outlet





In cooperation with:

Domonkos Tolnai
HZG

High-energy SRμCT at PETRA III / DESY

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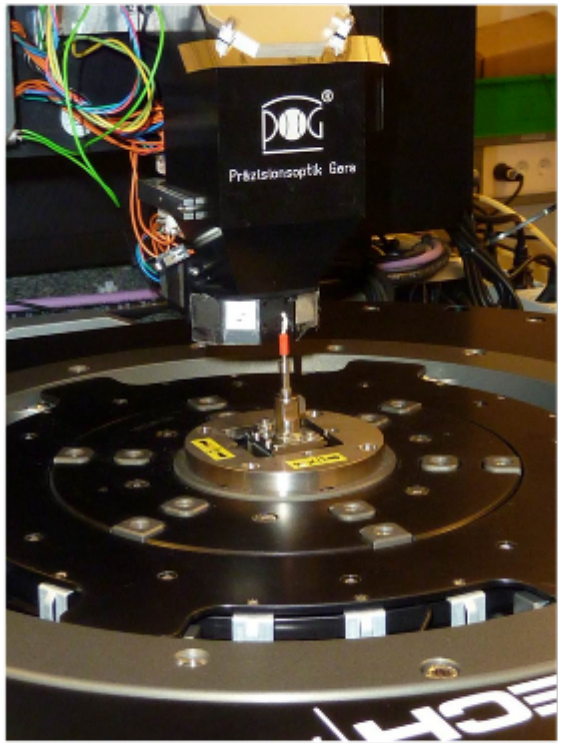
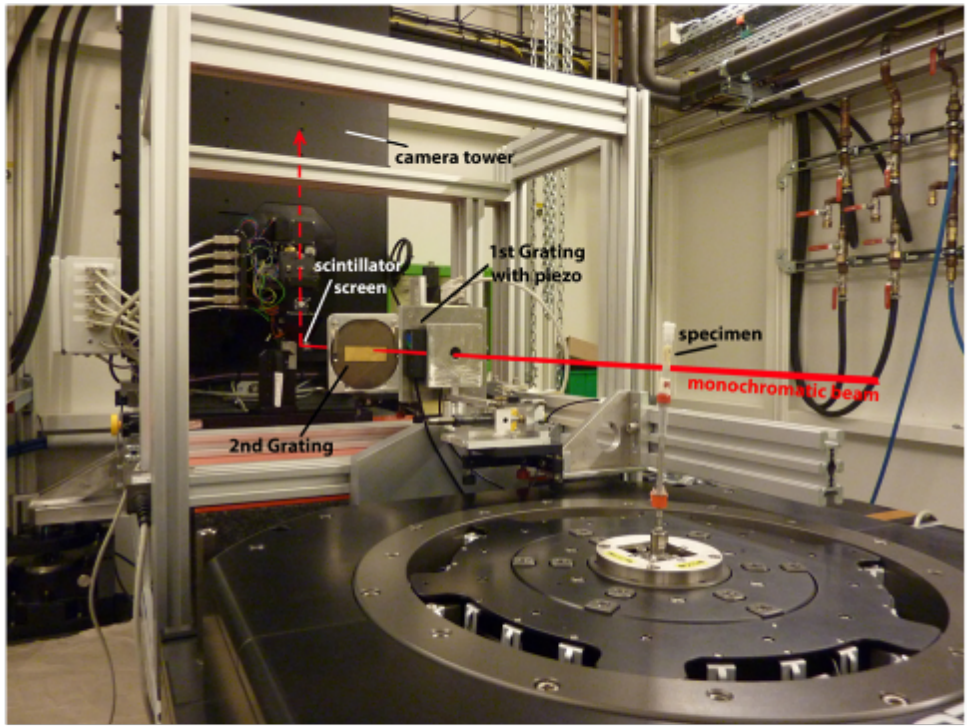
Attenuation contrast



Phase contrast



- high throughput microtomography (sample changer)
- standard data format, online reconstruction
- DPC user experiment for 33 , 40, 82, 100 keV

Tilted Grating Setup, first test

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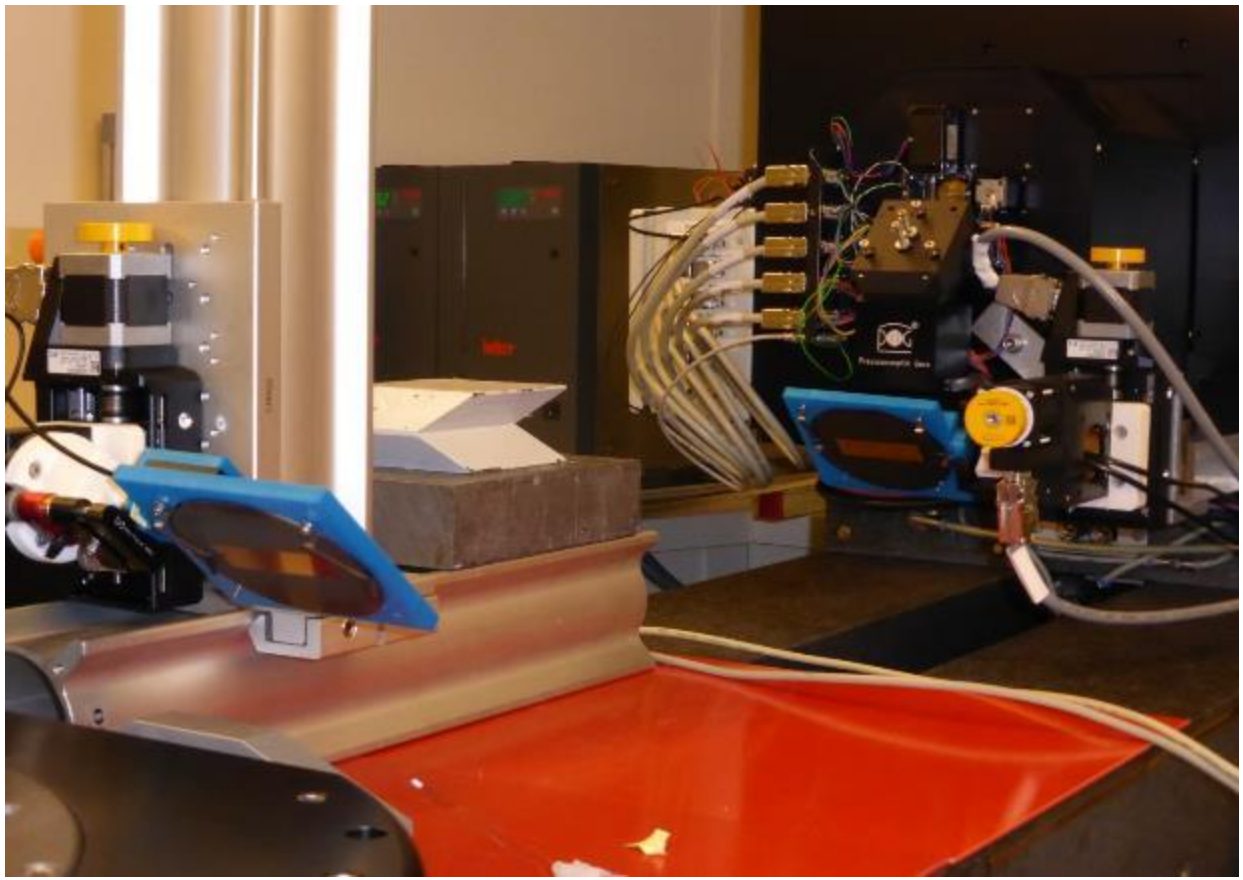

G1: effective height always matching energy

G2: effective height compensates for lower attenuation coefficient.

Effective heights:

35 keV: G1 6.1µm, G2 120µm
60 keV: G1 10.5µm, **G2 206µm**
100 keV: G1 17.6µm, **G2 364µm**

P07 (HEMS) - Setup

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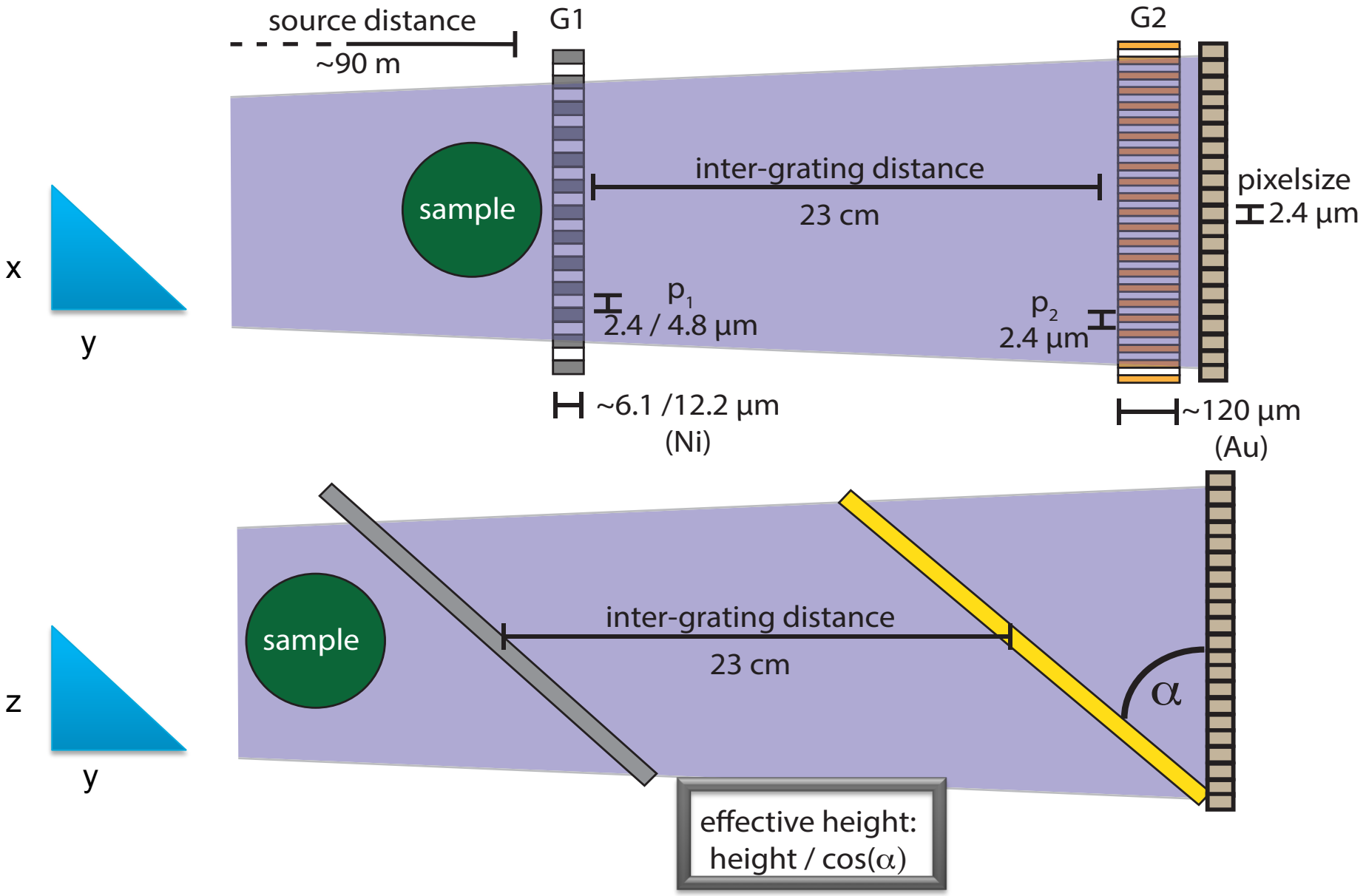
Zentrum für Material- und Küstenforschung



Tilted-grating setup for increased effective heights

Grating-based µCT at P07

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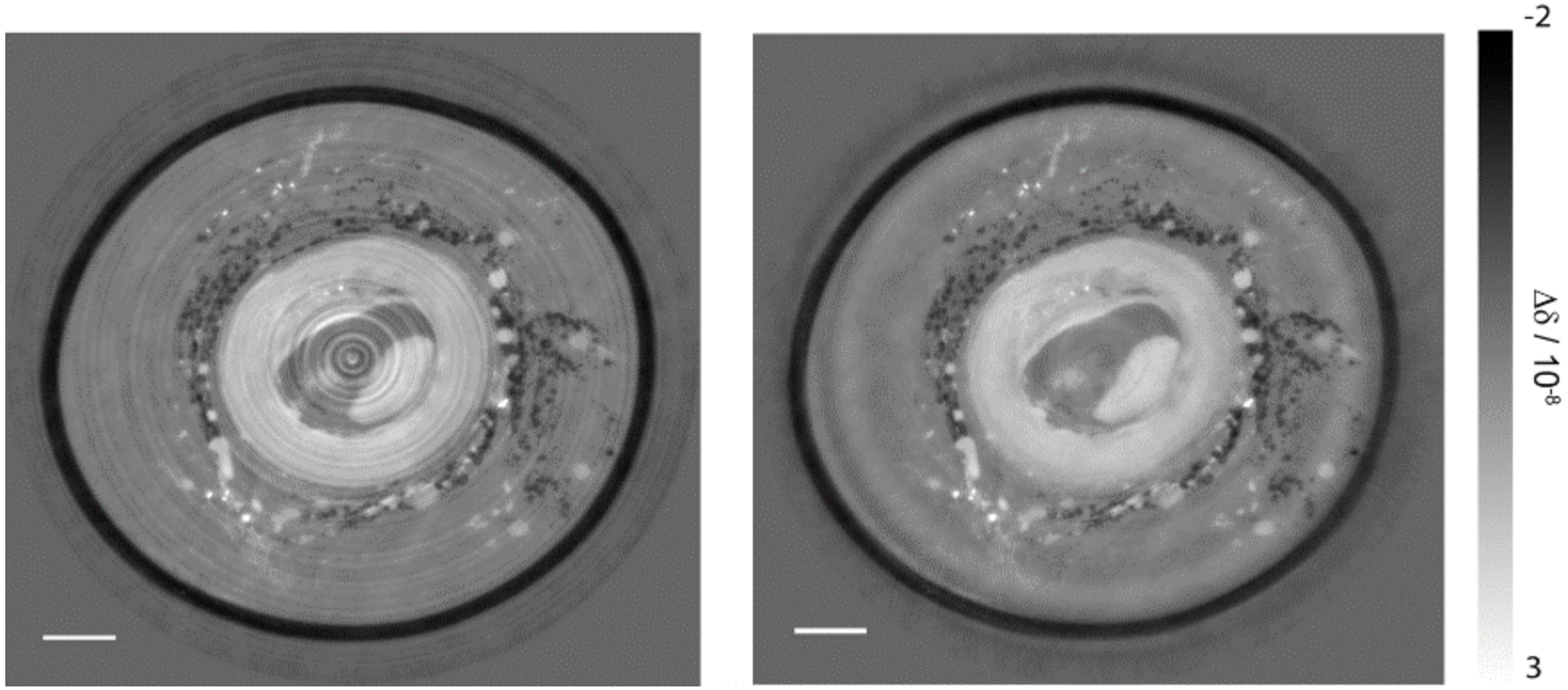
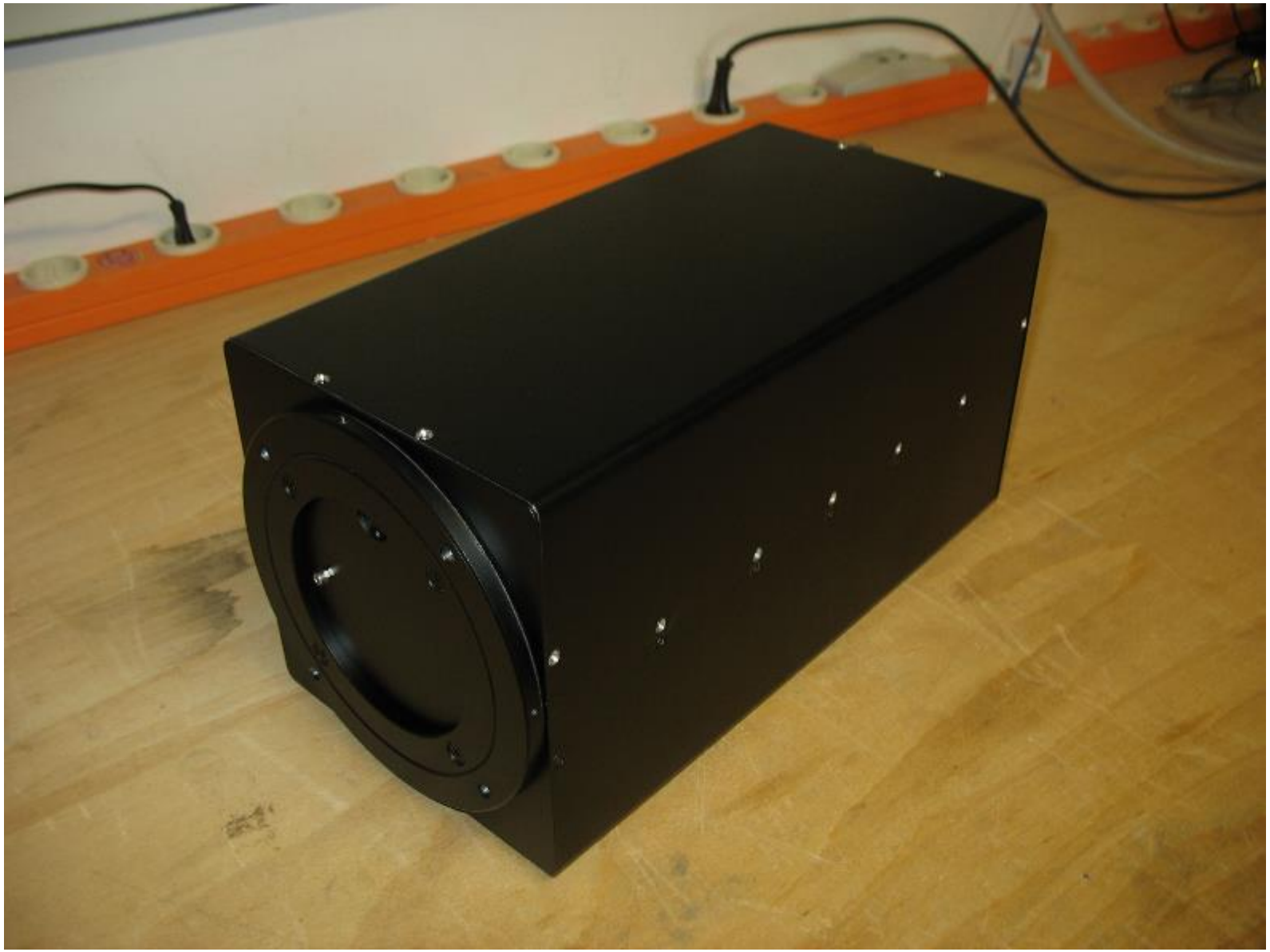
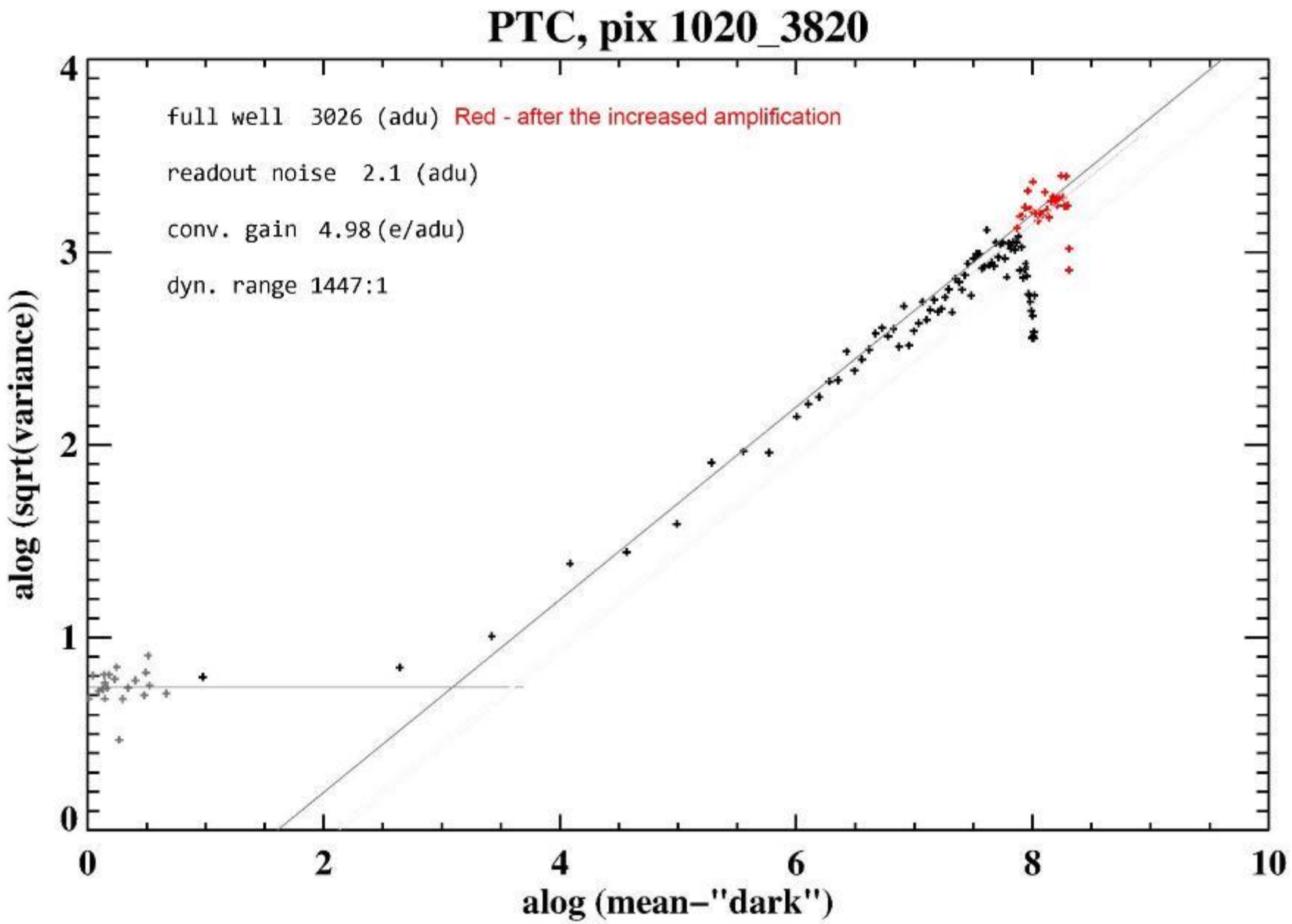


Virtual human coronary artery slices from SRµCT in phase contrast mode: original data (left) compared with data improved using a wavelet-Fourier filtering (right), where the ring artifacts are removed. Scale bar corresponds to 1 mm. ref. Optics Express **17** (2009) 8567-8591

20 MPIX CMOS-KIT camera (part of UFO)



Photon transfer curve, left side of the sensor



Conversion gain distribution

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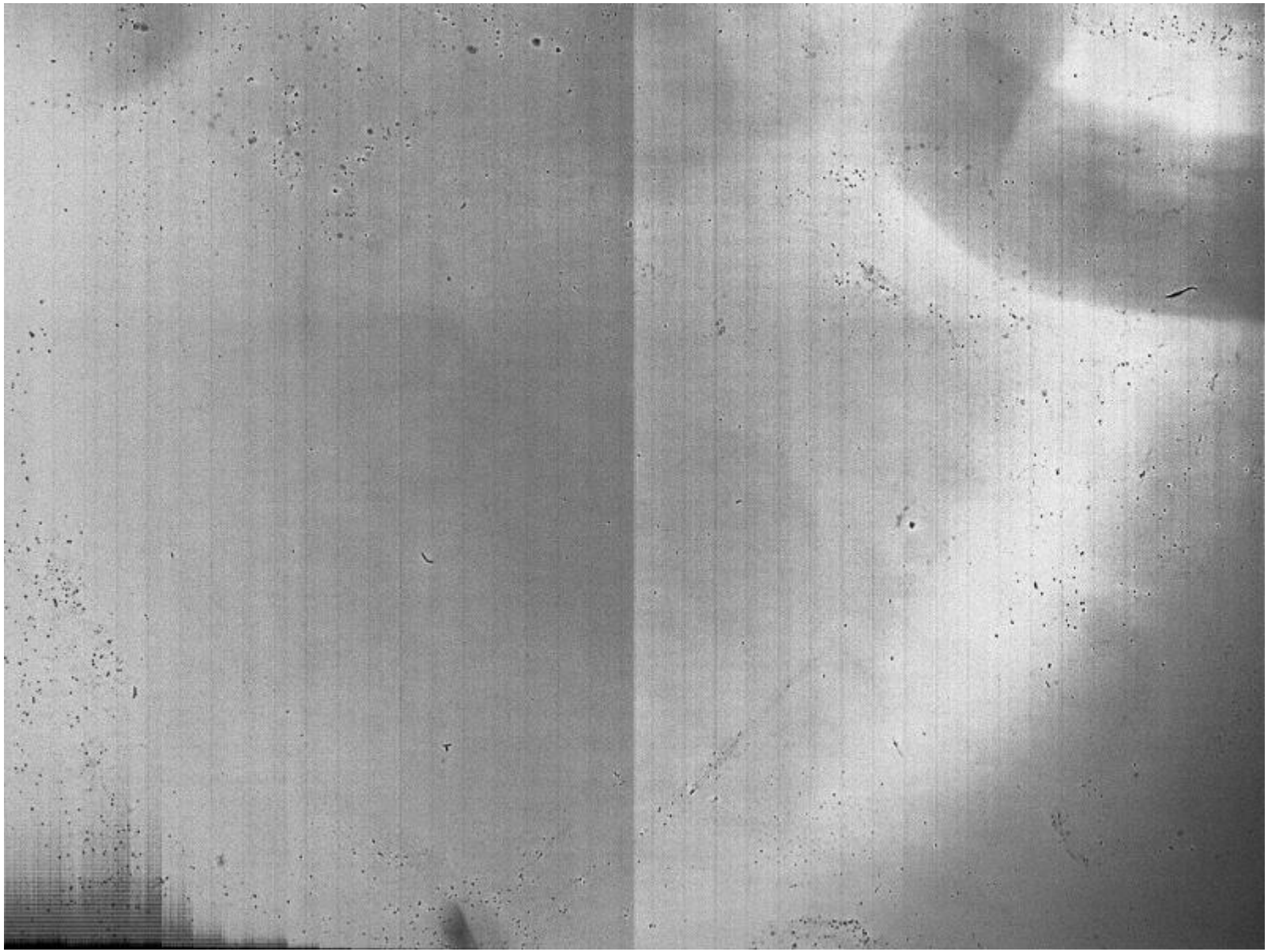

black = 3 (e/ADU)

white = 7 (e/ADU)

P05 (IBL) - Setup

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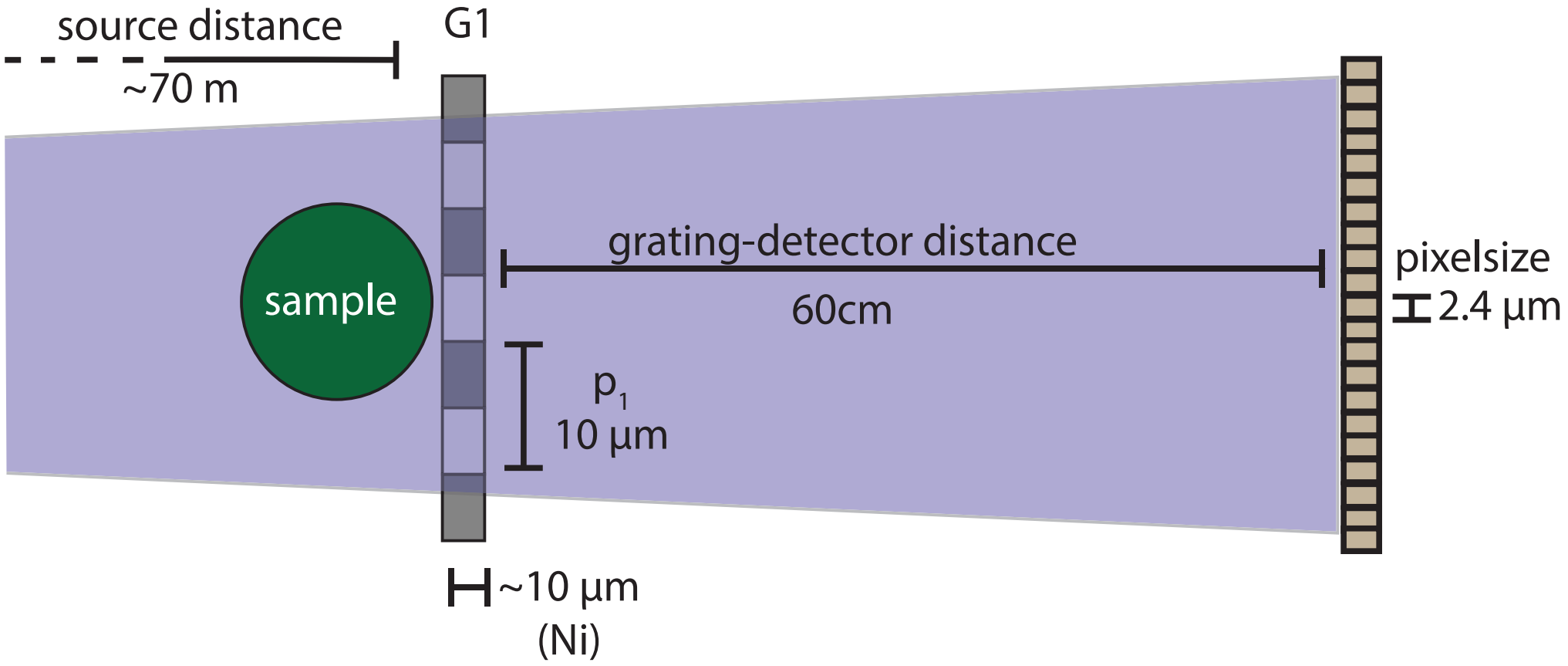
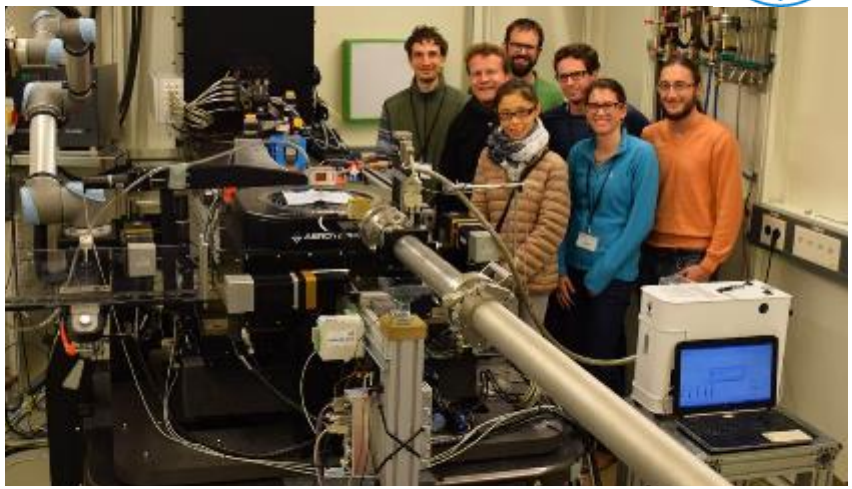


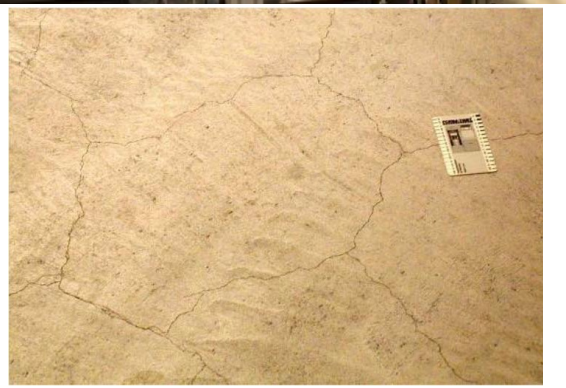
Single-grating setup for fast one-shot measurements and high-resolution stepping scans

Fast Talbot interferometry for **multi-contrast** X-ray imaging of water transport in porous materials

- DESY beamtime, Sept. 21st – 25th 2015, beamline P07
- In collaboration with A. Hipp, F. Beckmann and other colleagues from Univ. Gent (Belgium) and Univ. Pau (France)

- **Scientific goals**:
  - image the **water redistribution** in **cement-based materials** due to **evaporative drying** through one boundary surface
  - **feed in analytical** and **computational models** of **drying shrinkage** and corresponding **cracking** (Nanocem university/industry consortium core project n°13)





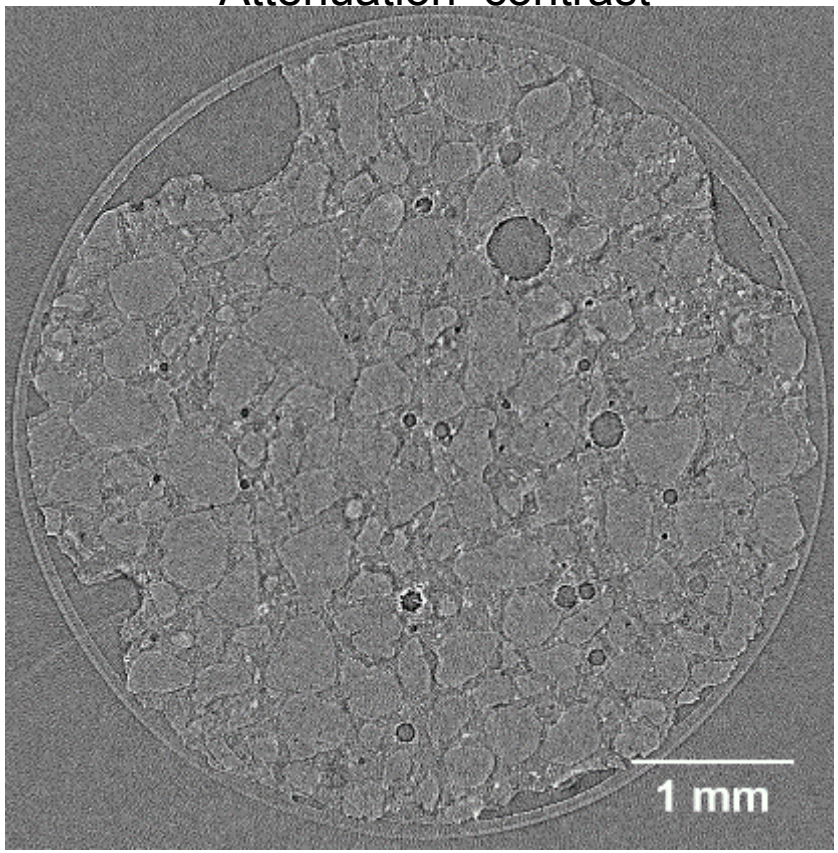
early age drying shrinkage cracks in a concrete pavement

For courtesy of R. Loser, Concrete/Construction Chemistry Lab., Empa

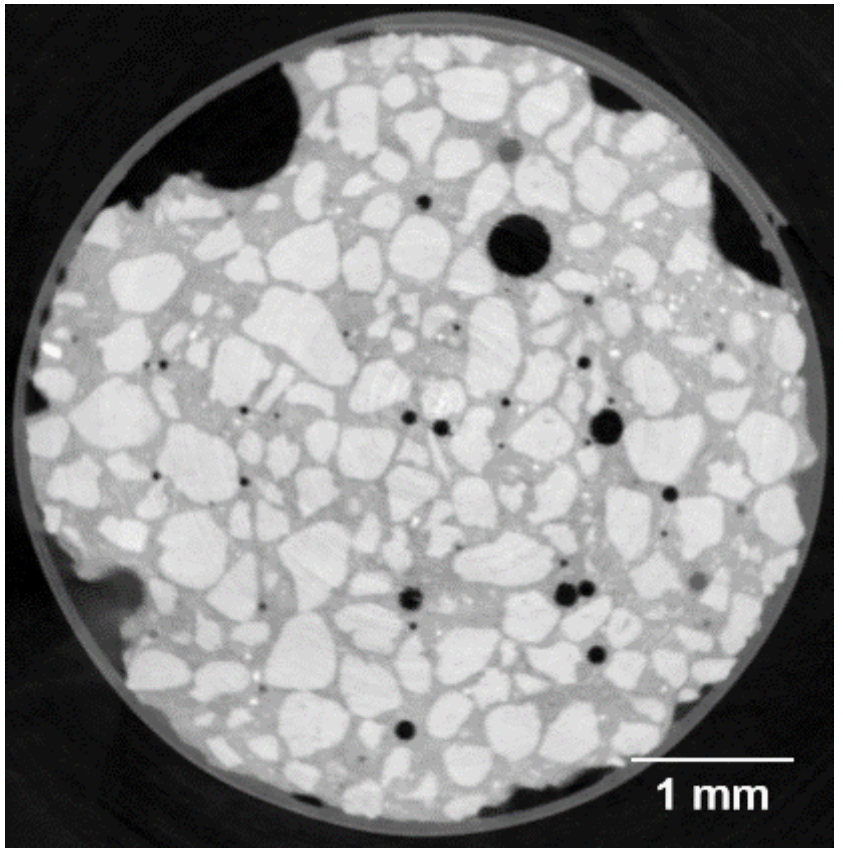
Fast Talbot interferometry for **multi-contrast** X-ray imaging of water transport in porous materials

- Image processing and analysis **ongoing**
- Some first preliminary (**very goooood**) results:
  - mortar samples still saturated

Attenuation contrast



Phase contrast

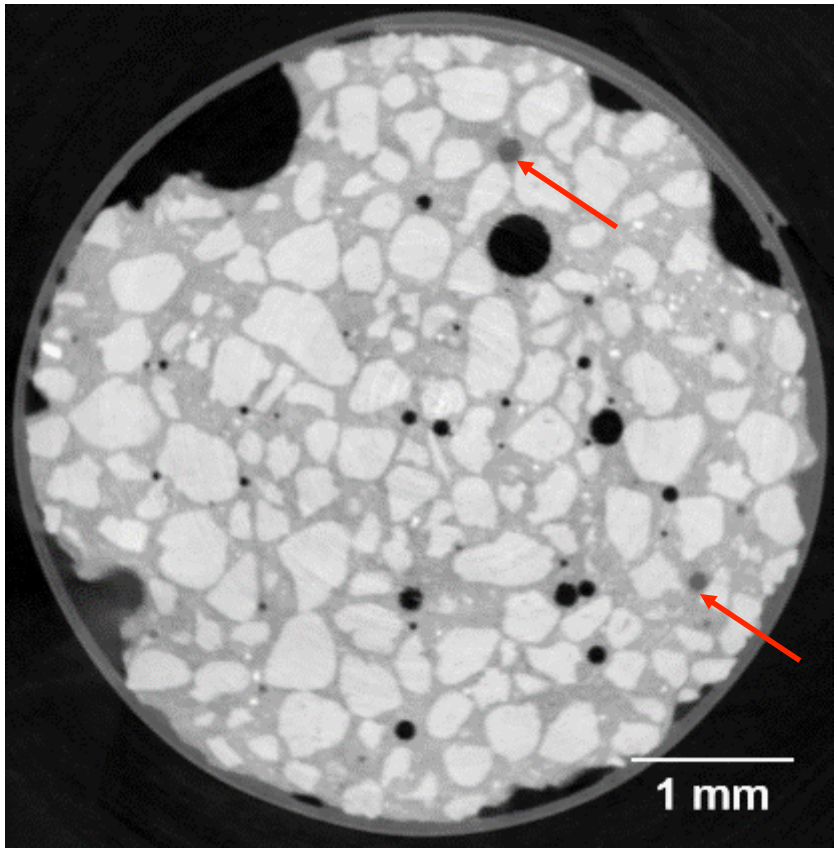


Take home message: XPCI by TLI provides much more contrast between aggregates and cement matrix ⇒ **image analysis**, e.g., segmentation, **gets easier** ⇒ **computational modeling** of **mesostructure** from CT data

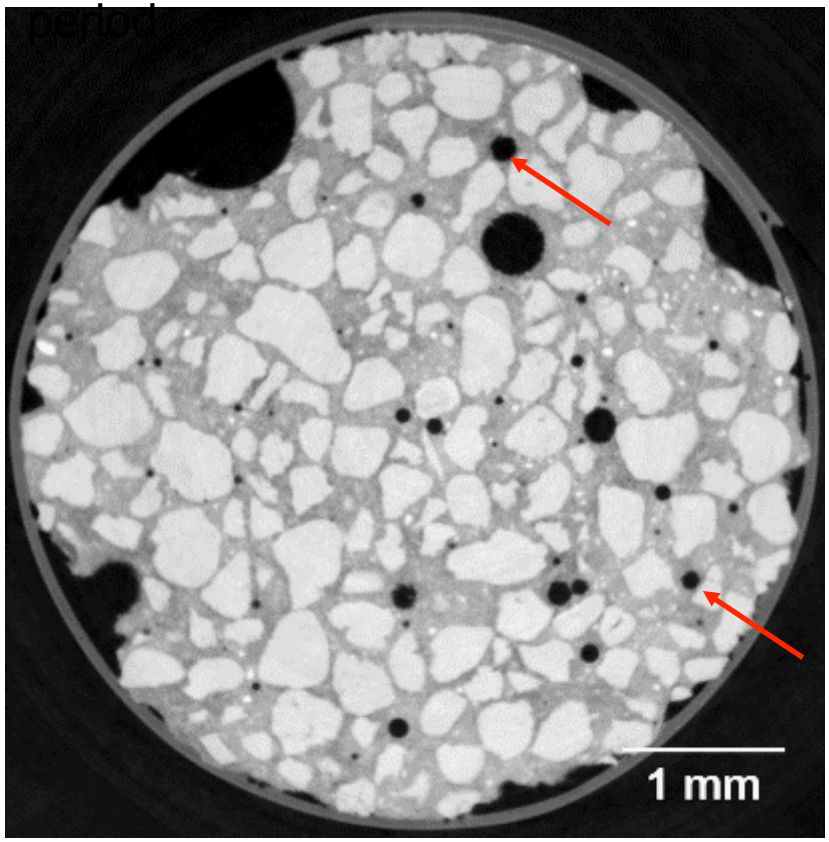
Fast Talbot interferometry for **multi-contrast** X-ray imaging of water transport in porous materials

- Image processing and analysis **ongoing**
- Some first preliminary (**very goooood**) results:

phase contrast, saturated state



phase contrast, drying falling rate period



Take home message: even without any time-differential analysis, water loss is visible by the eye in the largest pore, while it's barely visible in the attenuation tomograms. The cement matrix got also darker.

Use of ASAP3

Andre Rothkirch, DESY

Helmholtz-Zentrum Geesthacht
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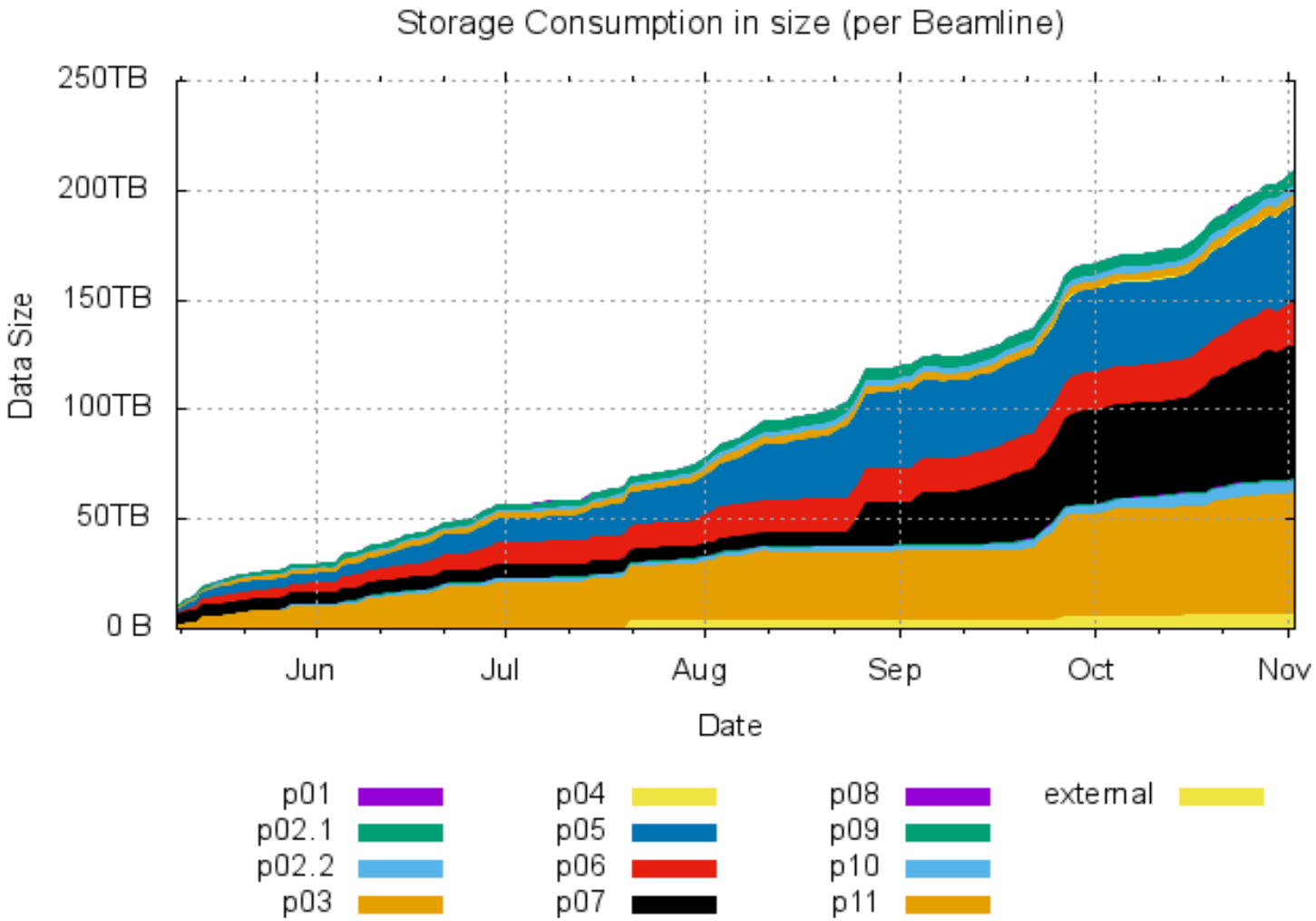

Microtomography at P05 / P07

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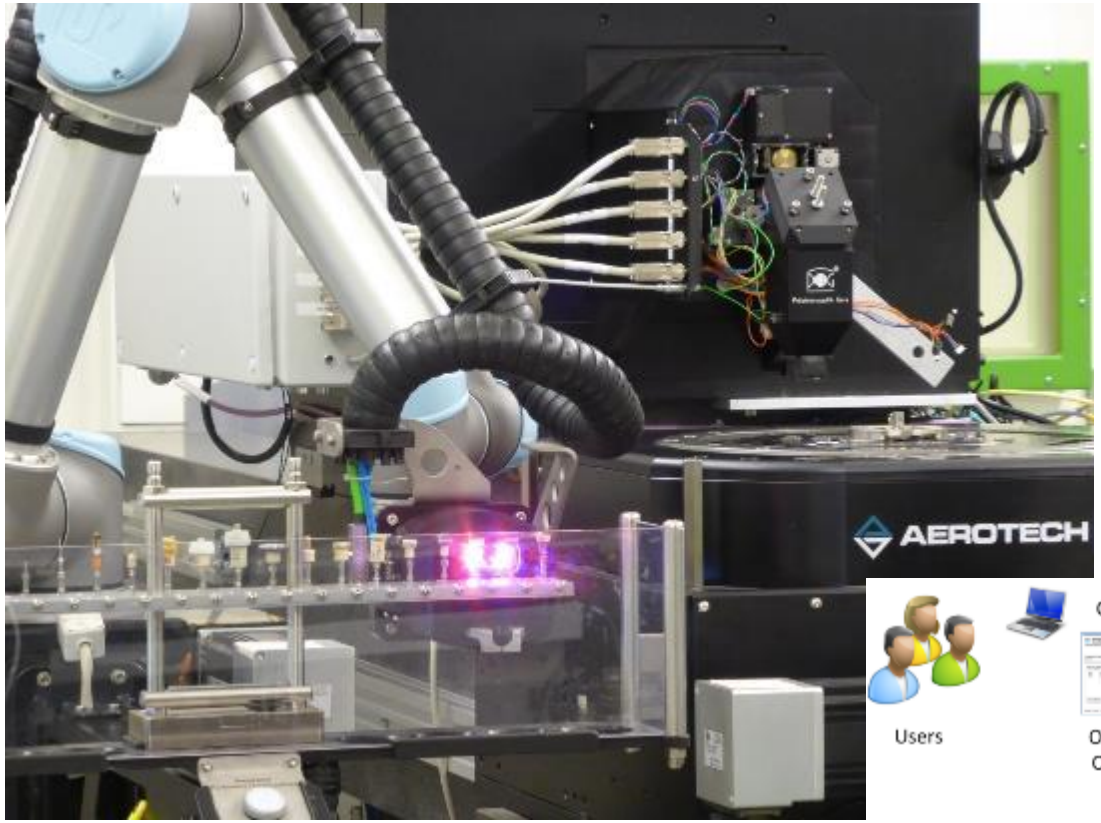
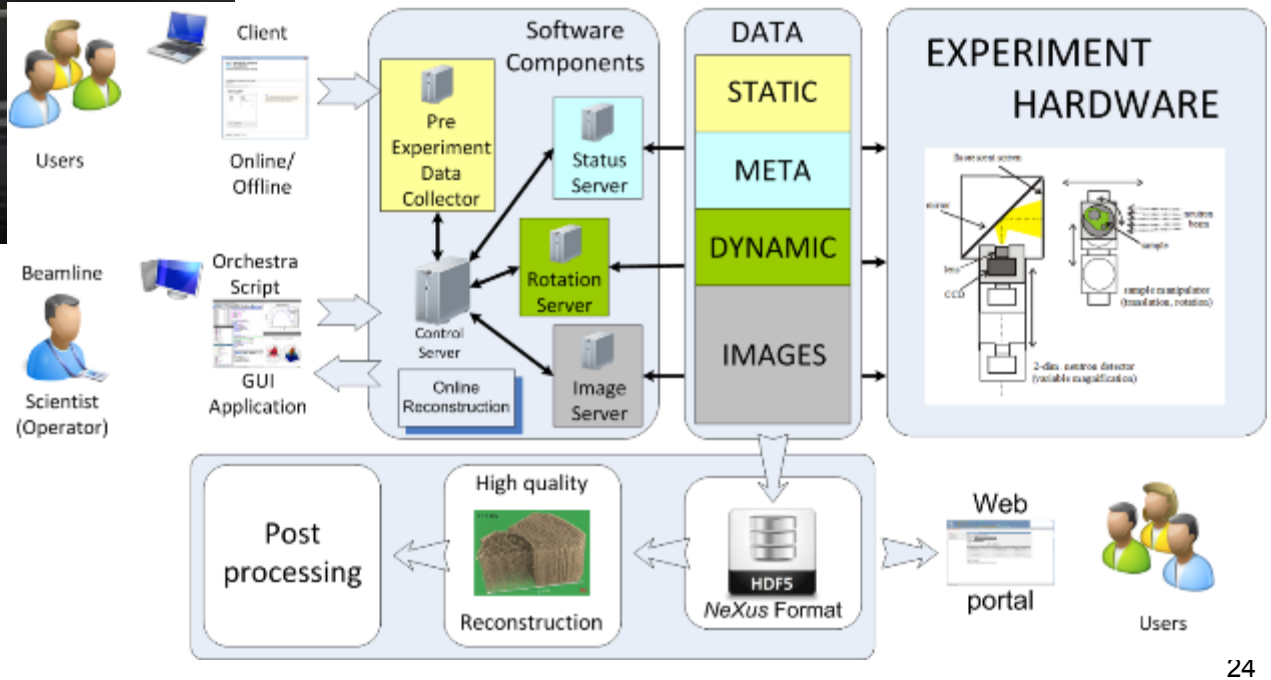


Integration of automatic sample changer:

- 20 samples (up to 20 mm diameter, 200 g)
- Standardized sample holder
- Integrated sample ID (QR matrix)
- Sample pre investigation (visible light, nanotom S)

New software concept:

- Control for high throughput SRµCT
- Standardized data format
- Use of DESY IT infrastructure



Parallel Computing for SRμCT: Reconstruction

Pre-Reconstruction

- Image correlation for best flat field (P05)
- Automatic determination of center of rotation

Real-Time-Reconstruction

- online monitoring to control ongoing scan
- Implemented by Tango-Server using UFO-Reconstruction by sequential filled sinograms

High-Quality-Reconstruction

- Best use of the photon statistic (scanning applications)
- Based on intensities (not on calibrated sinograms)
- Iterativ reconstruction techniques

Parallel Computing for SRμCT: Detector

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GPU at the detector workstation

Real-Time-Data-Reduction

- Intelligent DPC-Detector (calculation of phase, absorption, dark field)
- Intensity combination and flat field correction for scanning technique

Timing mode of SR (challenging)

- Ultra-fast triggered CT

Parallel Computing for SRμCT: 3D-Volume

Virtual Data Evaluation Workstation

Software-library for standard filter

- Integration into standard software (IDL, Matlab, Avizo)
- Registration of multi-modal data sets

Visualization