

# Machine learning denoising of high-resolution nanotomography data

P05 nanotomography

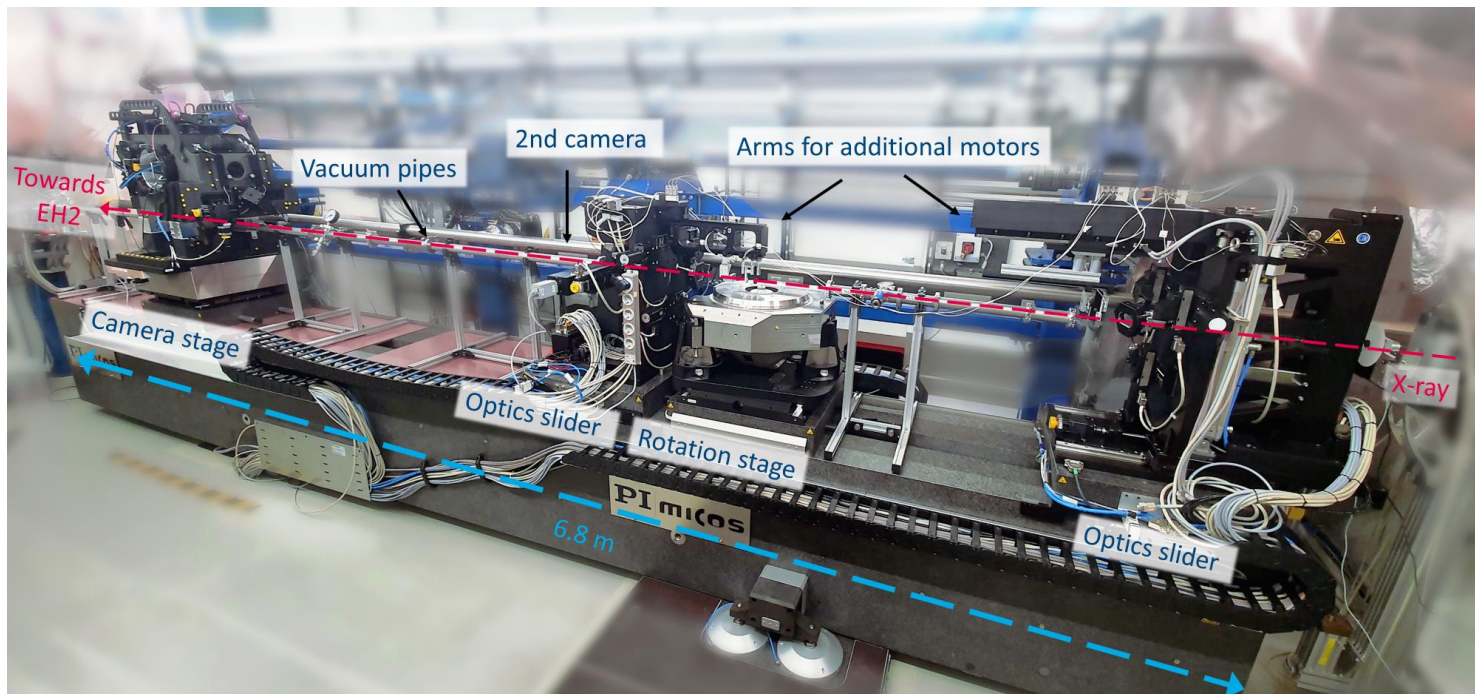
**Silja Flenner**

Institute for Materials Research

5th Round Table on Deep Learning at  
DESY 2022

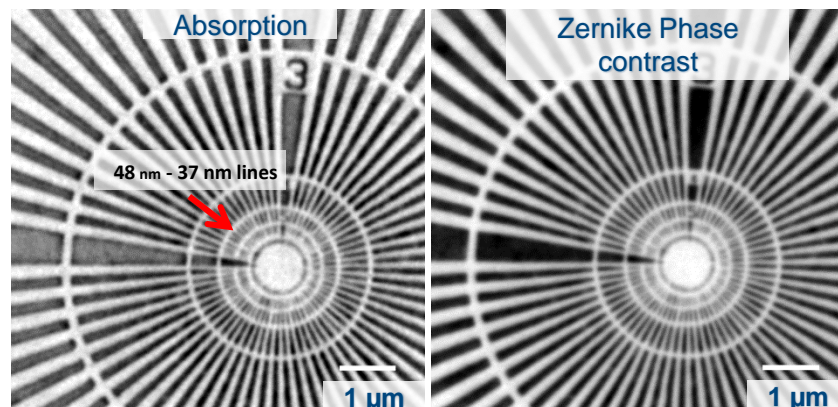


# Full-field nanotomography @ P05, PETRA III, DESY

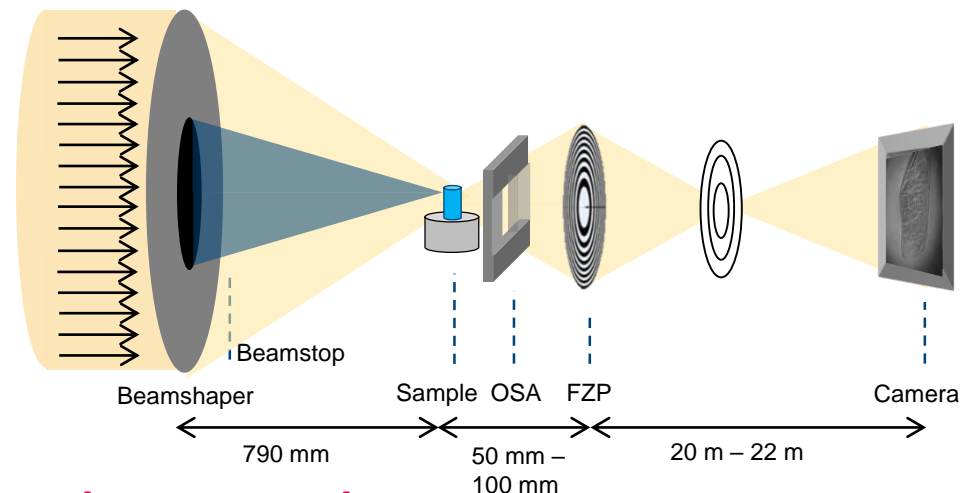


**Nanotomography:**

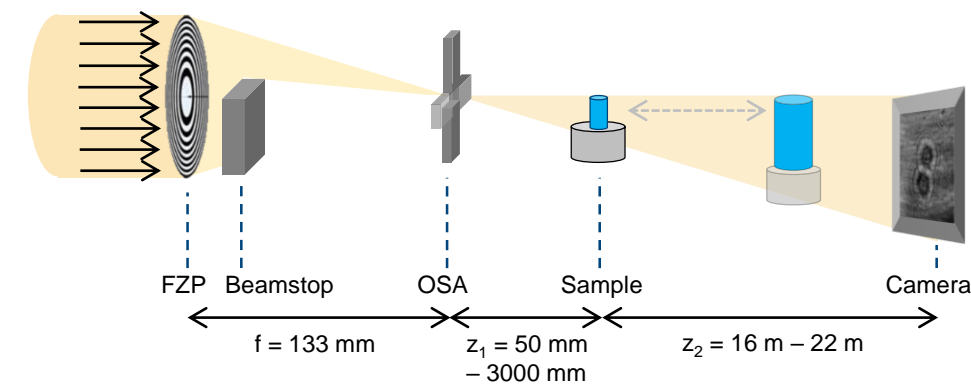
- Resolution < 50 nm
- Standard scans 15 min
- Fast scanning
- *In situ* applications



## Transmission X-ray Microscopy



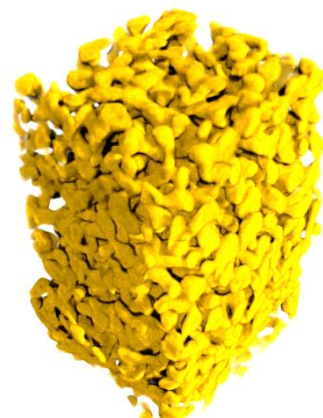
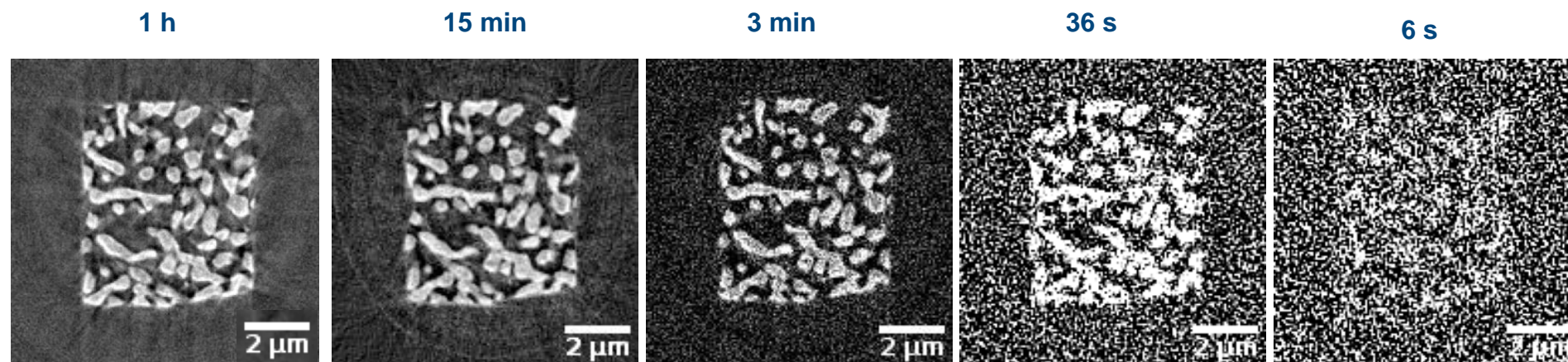
## Holotomography



Flenner et al. Journal of Synchrotron Radiation, (2020)

Flenner et al. Optics Express (2020)

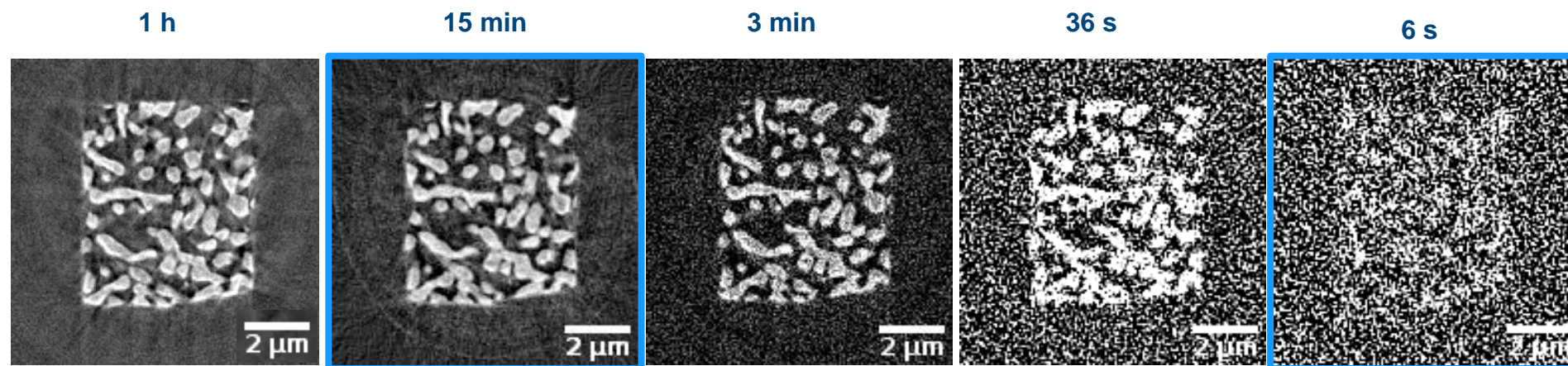
# Machine learning for high time resolution



**Nanoporous gold**

3D test pattern for  
Nanotomography

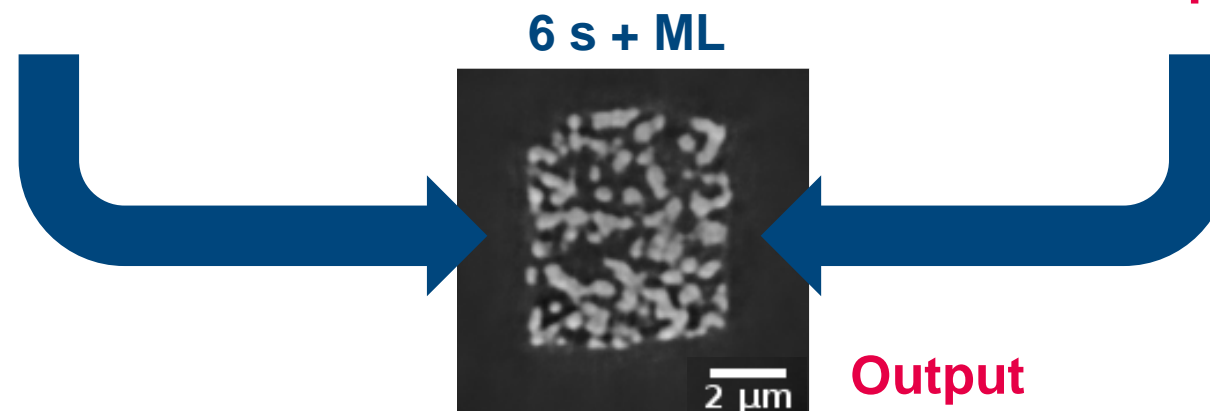
# Machine learning for high time resolution



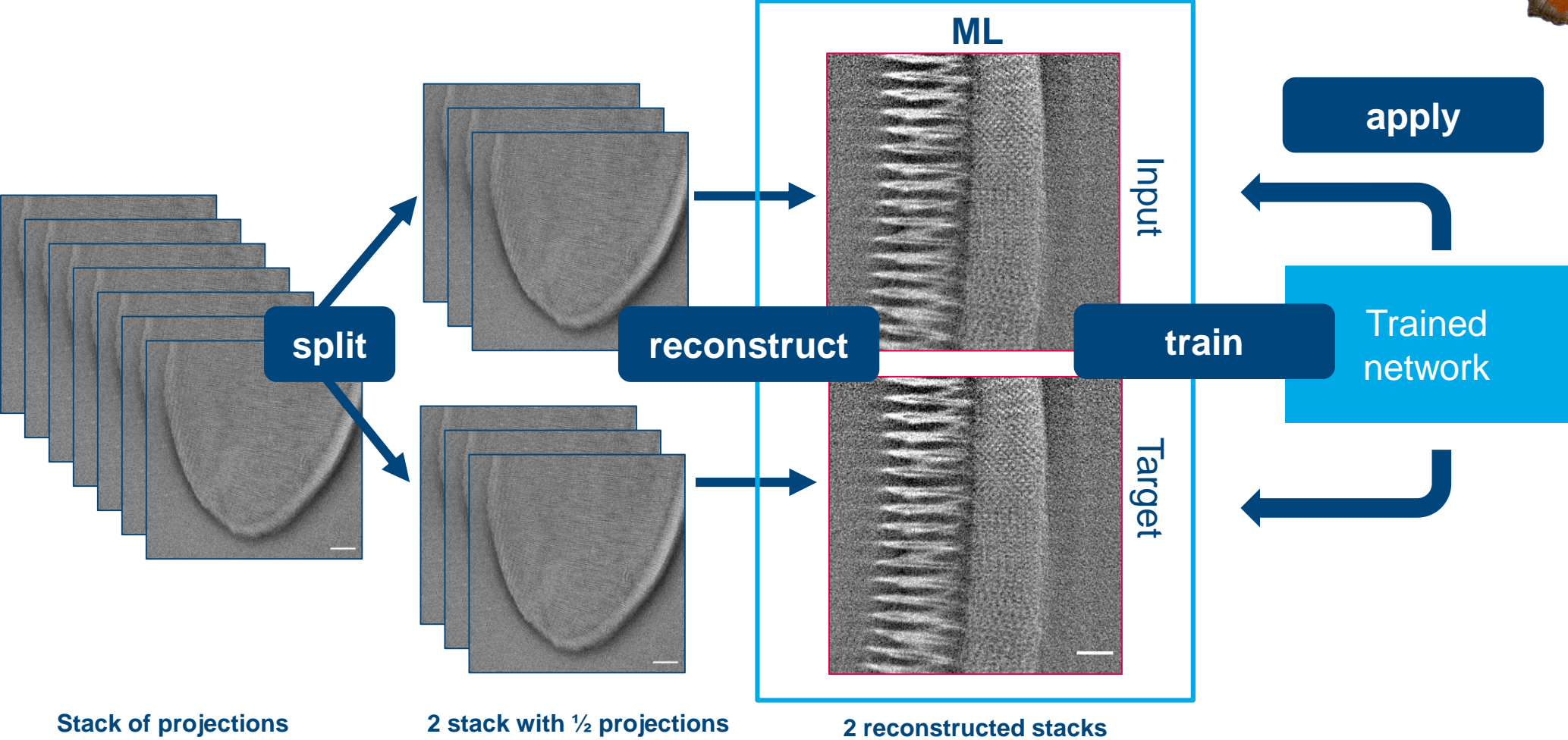
Reference

Input

Machine learning (ML) for  
very short scan times



# Machine learning denoising: Noise2Inverse

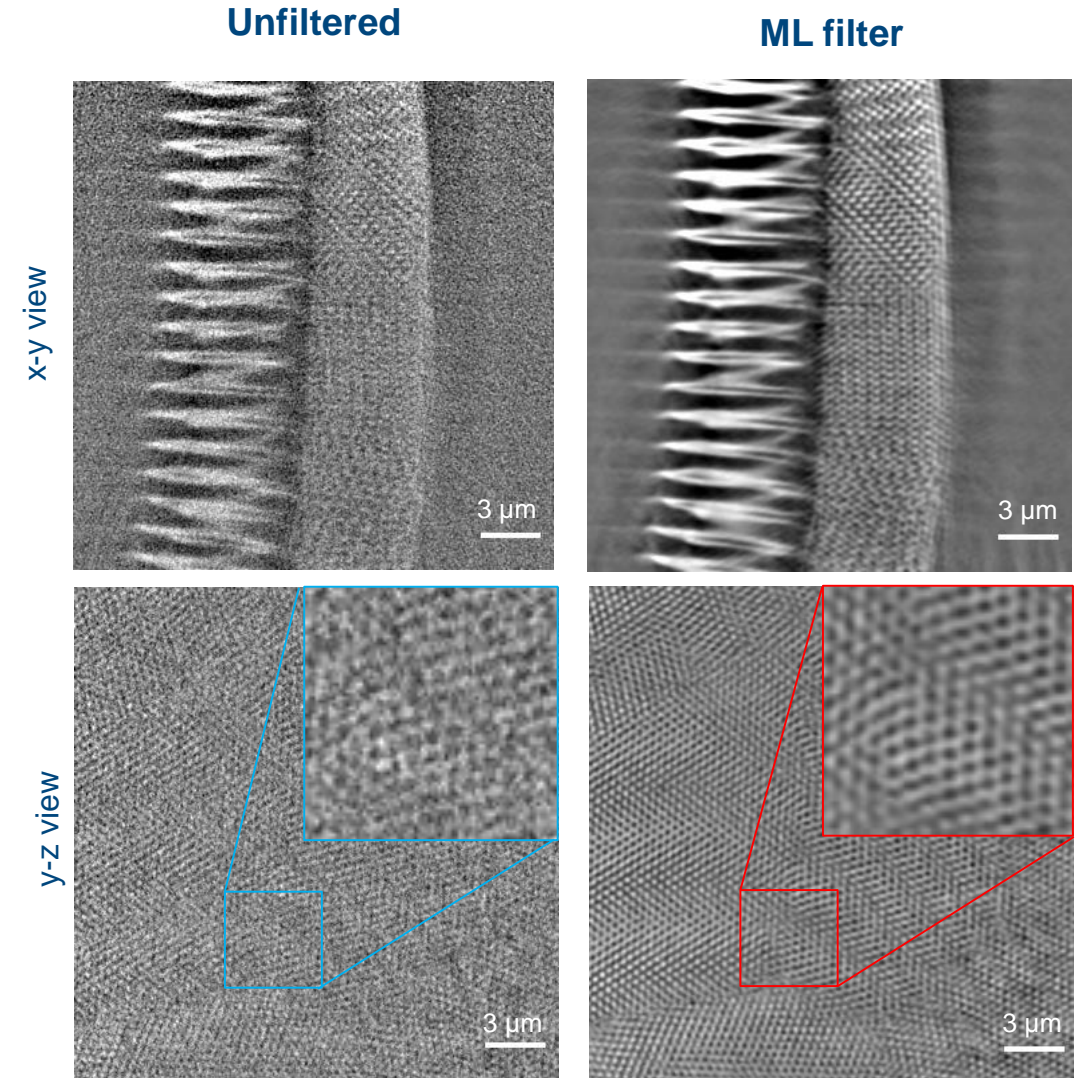
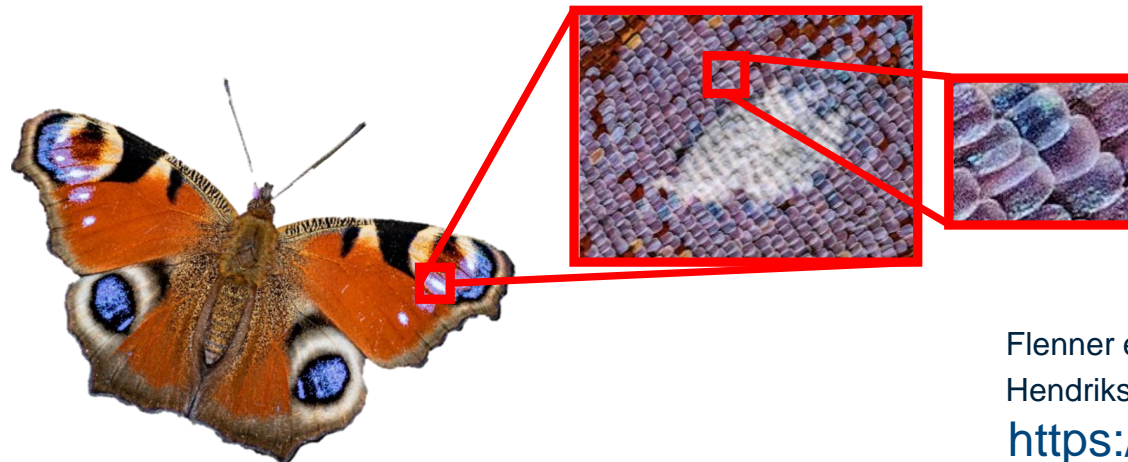


Hendriksen et al. (2020). *IEEE Transactions on Computational Imaging*  
Flenner et al. (2022) *Journal of Synchrotron Radiation*

# Denoising of standard scans

Applicable on standard scans without reference scan

- Multi-scale dense network (msdnet)
- 5 input channels (5 slices, 2.5D training)
- Image size: 1024 x 1024
- Training data size: 100 – 300 slices
- Test data size: 40 – 80 slices



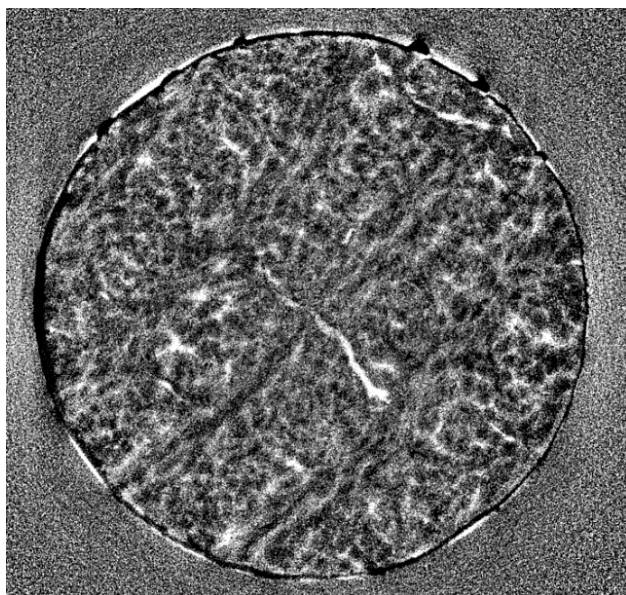
Flenner et al. (2022) *Journal of Synchrotron Radiation*  
Hendriksen et al. (2020). *IEEE Transactions on Computational Imaging*  
<https://github.com/dmpelt/msdnet>

# Applicability

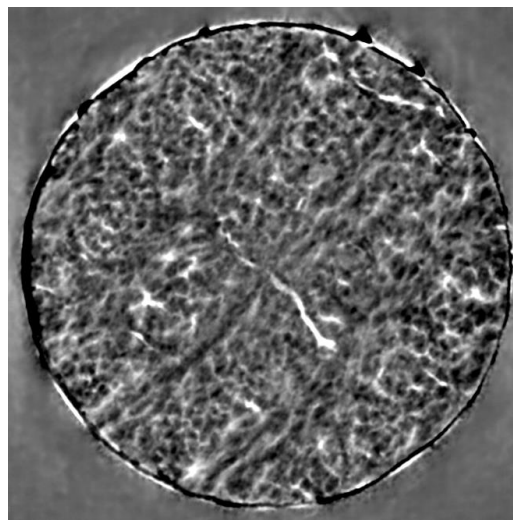
## 3D Human Bone Anatomy

Training is the most time consuming step (up to several hours)

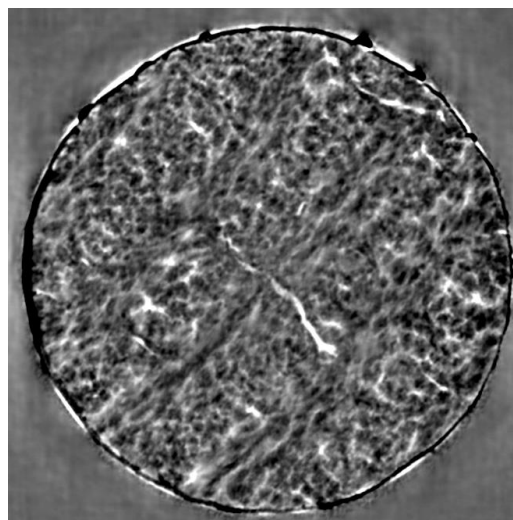
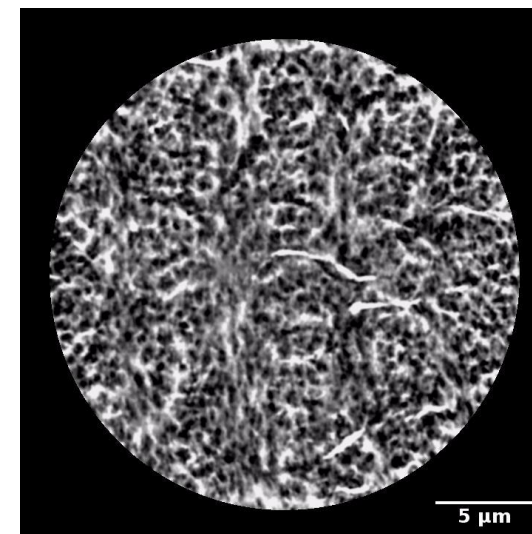
Typical TXM experiment:  
Batch of similar samples



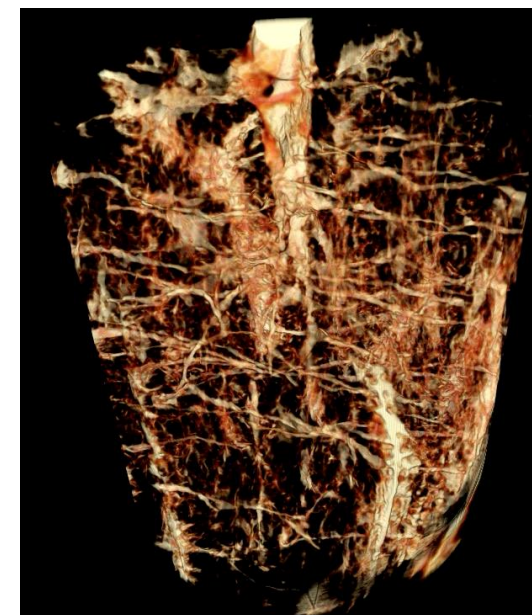
Original



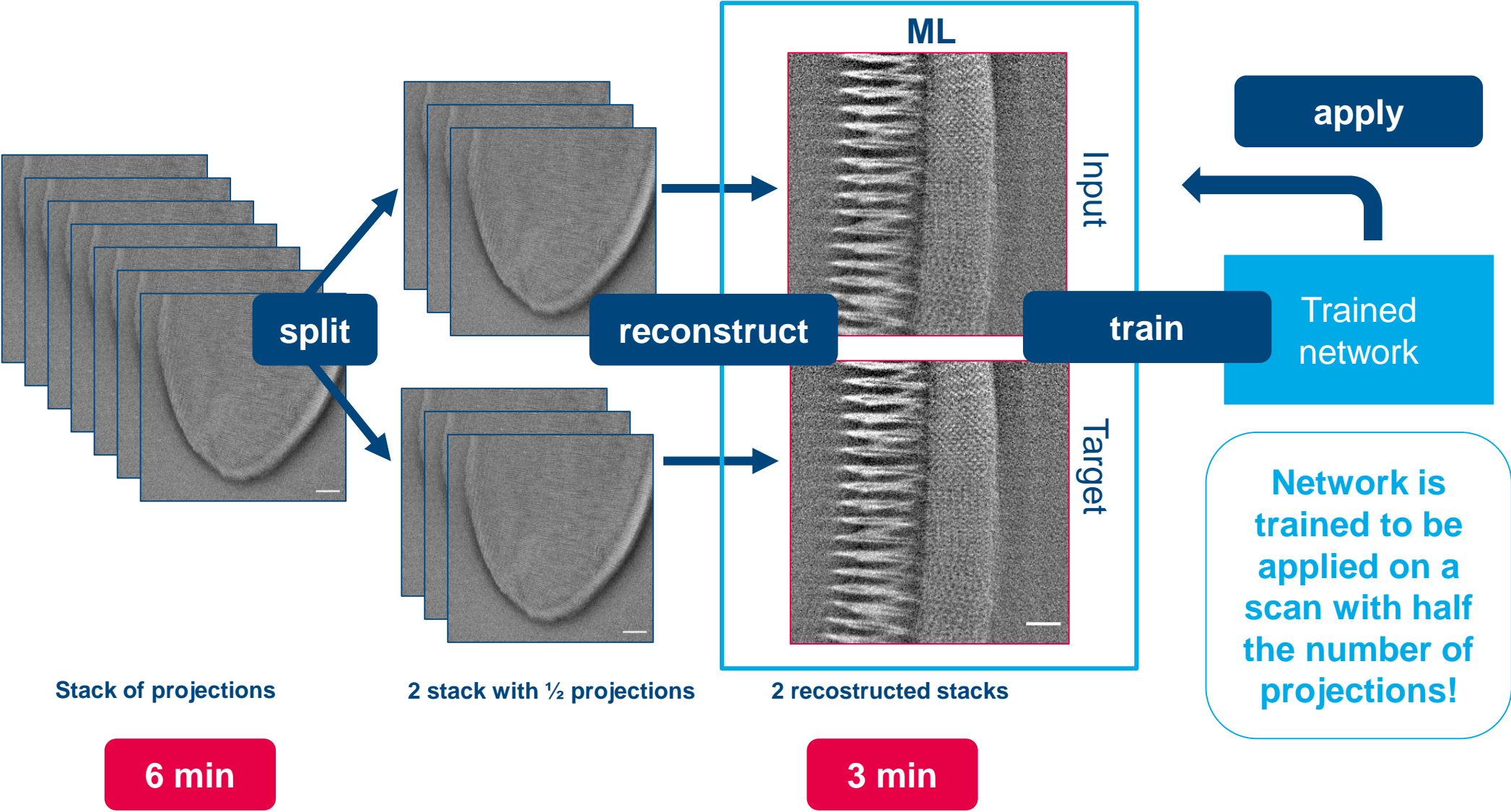
Trained on same sample



Trained on similar sample



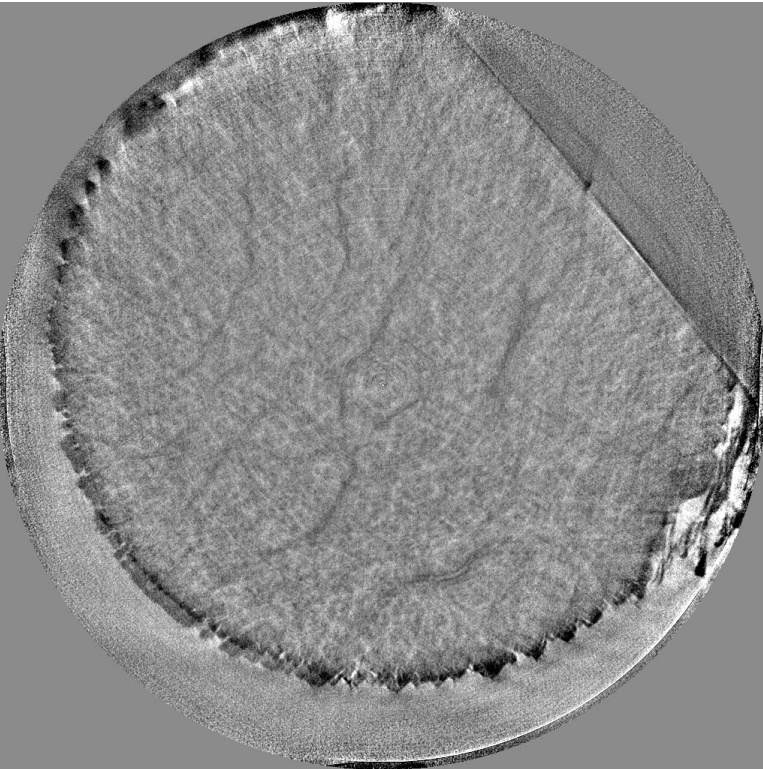
# Machine learning denoising



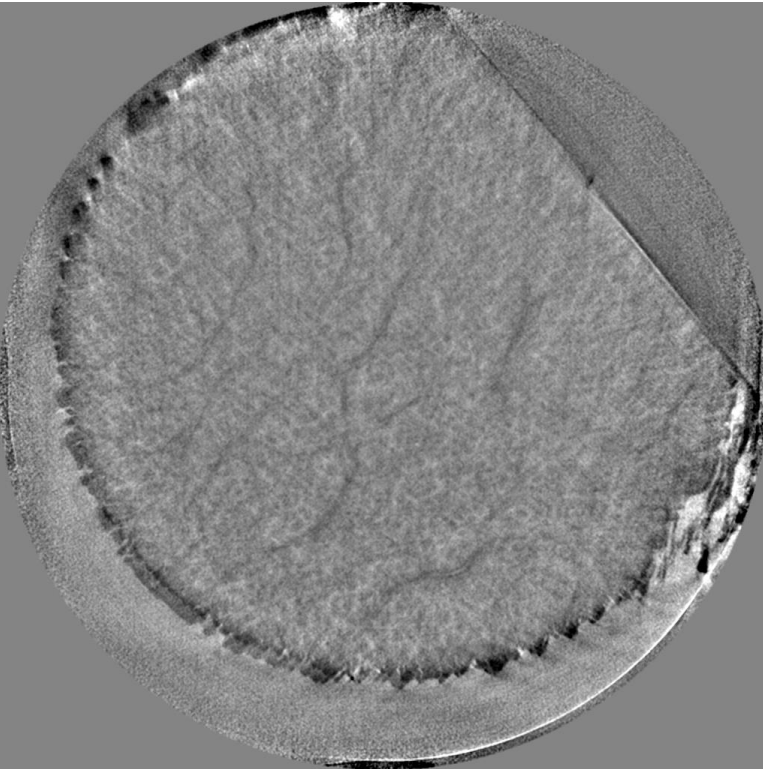


# Decreasing scan time for *in situ* experiments

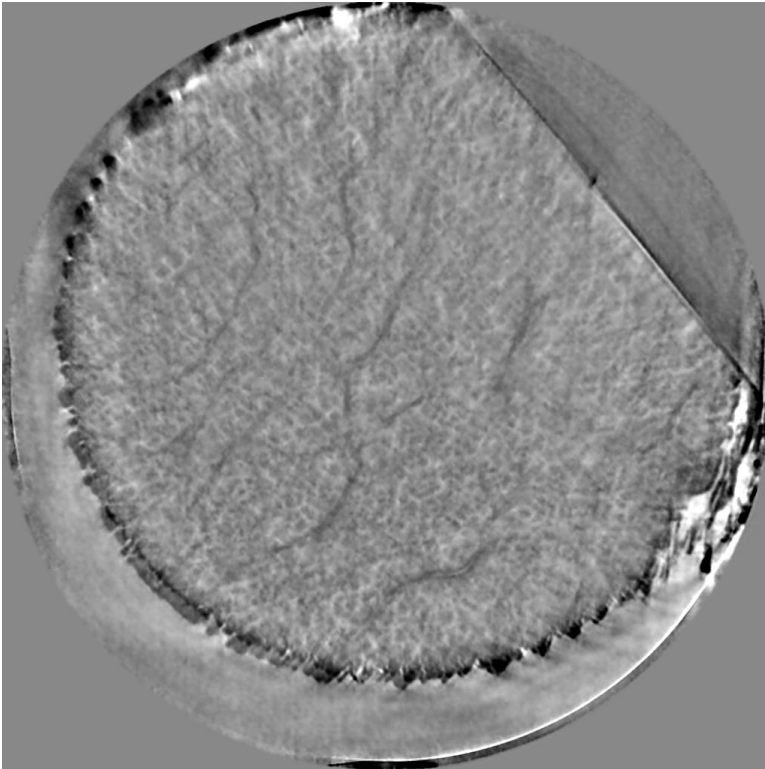
## 3D Human Bone Anatomy



6 min



3 min



3 min – ML filtered



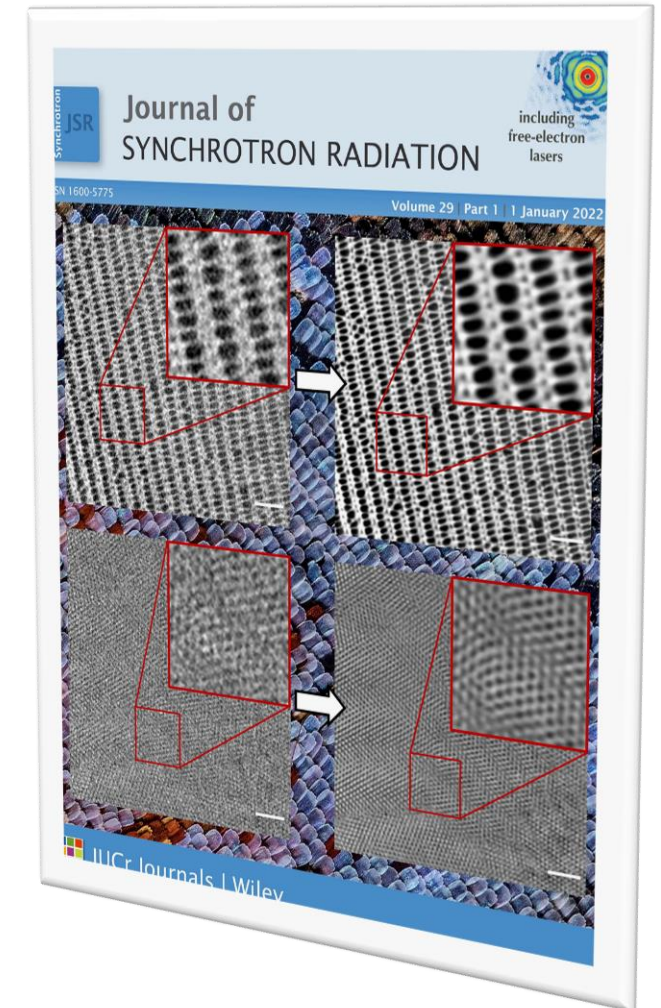
Trained network



# Summary

## Machine learning denoising

- Very short scans (with high quality reference scan)
- Standard scans without a reference scan
- Helps to reduce scan time for *in situ* experiments



# Thank you



## Hereon Team

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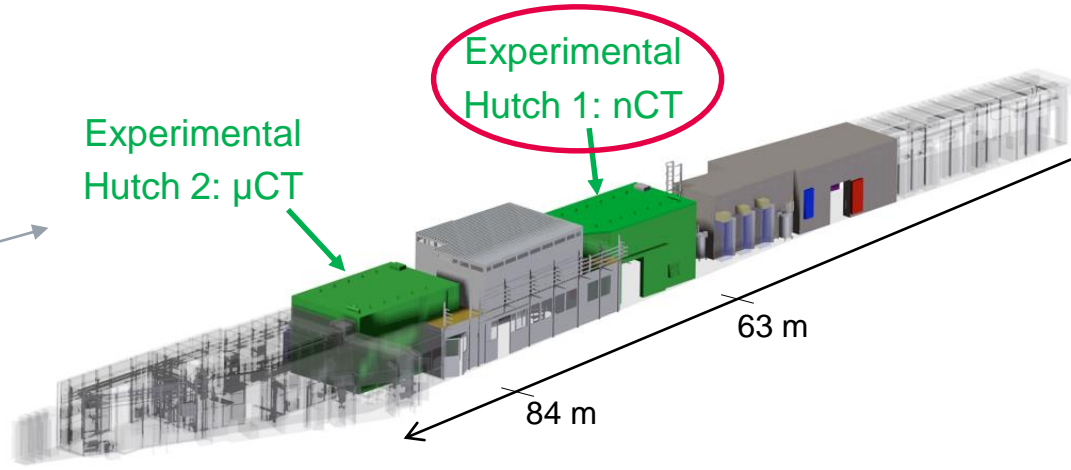


# Full-field nanotomography @ P05

<http://www.hamamatsu.com/eu/en/product/category/5000/5005/C12849-101U/index.html>

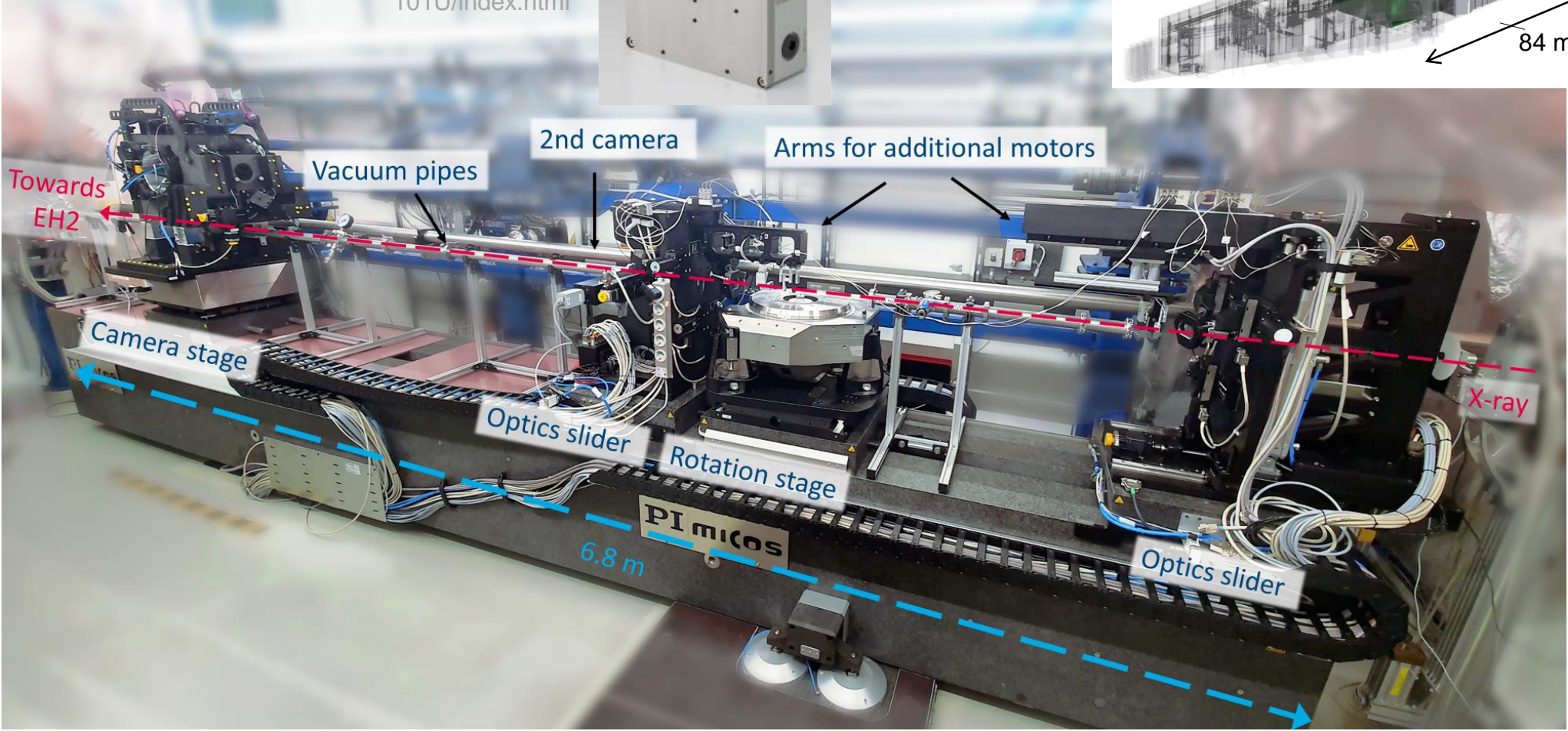


Camera



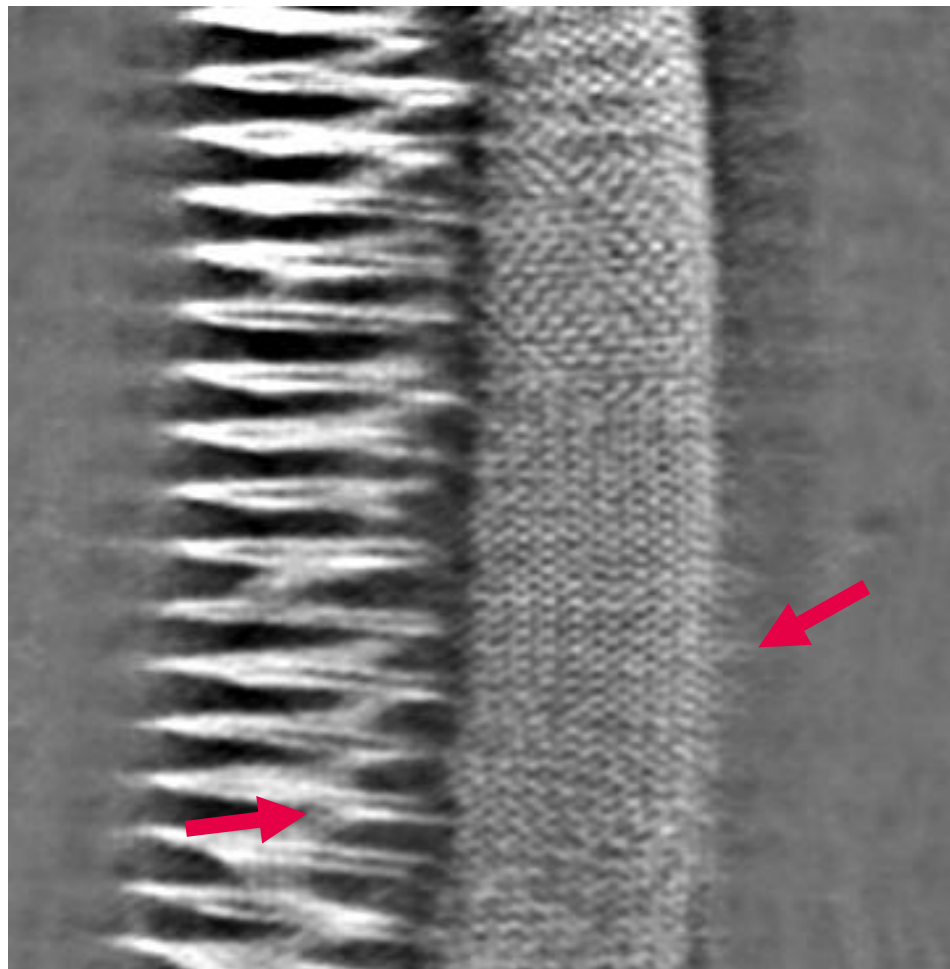
Imaging beamline P05 at PETRA III

Allowing a sample – detector distance of > 20 m!

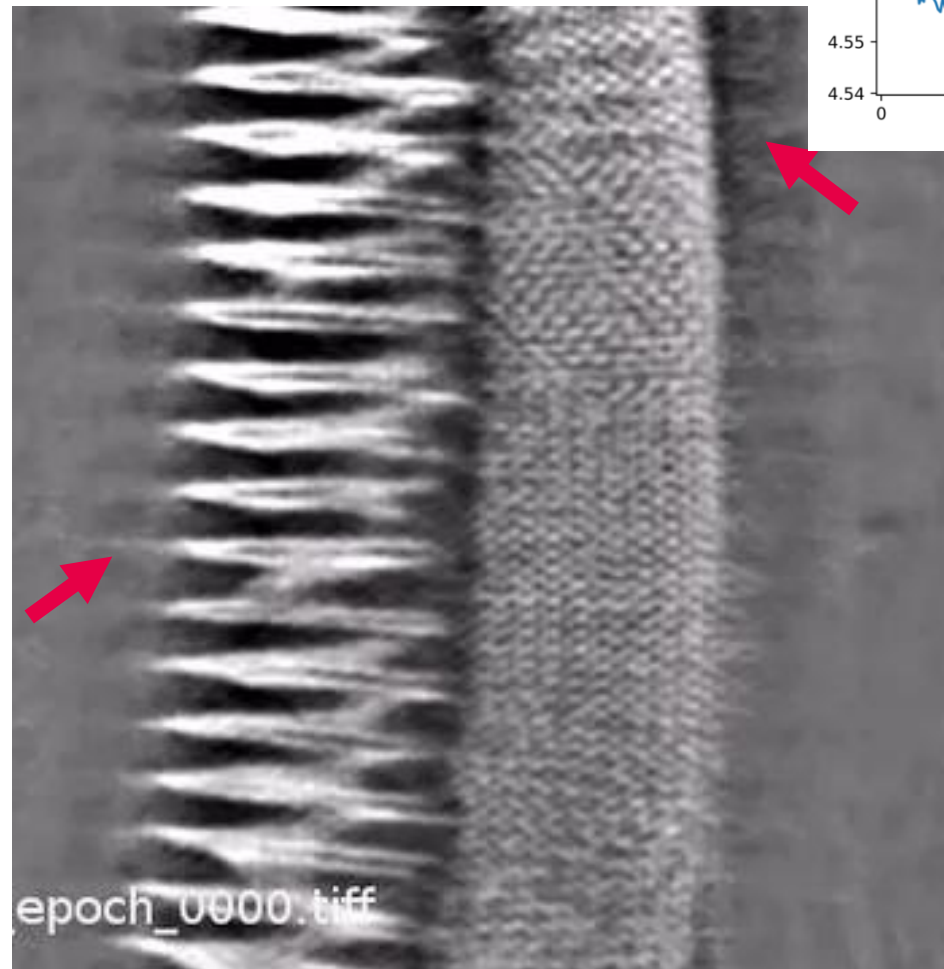


# ML denoising

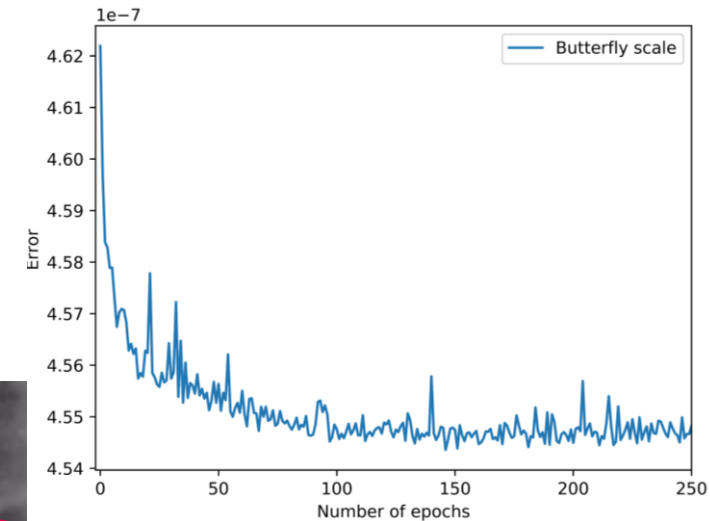
- Try to remove as many artifacts as possible before training! They will also be enhanced!



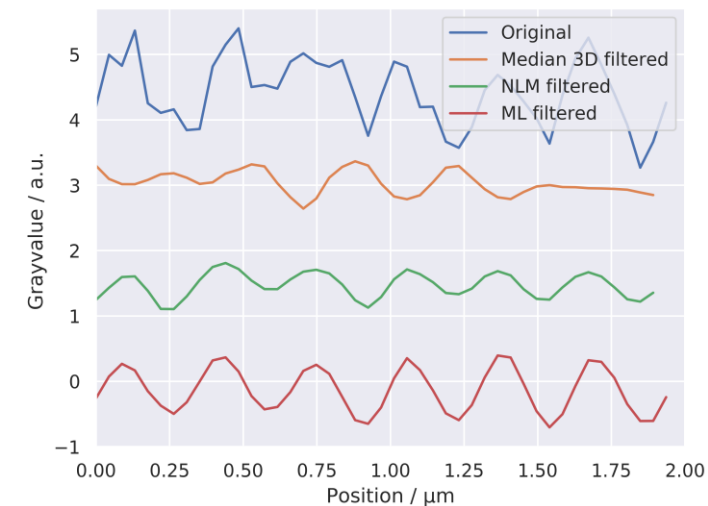
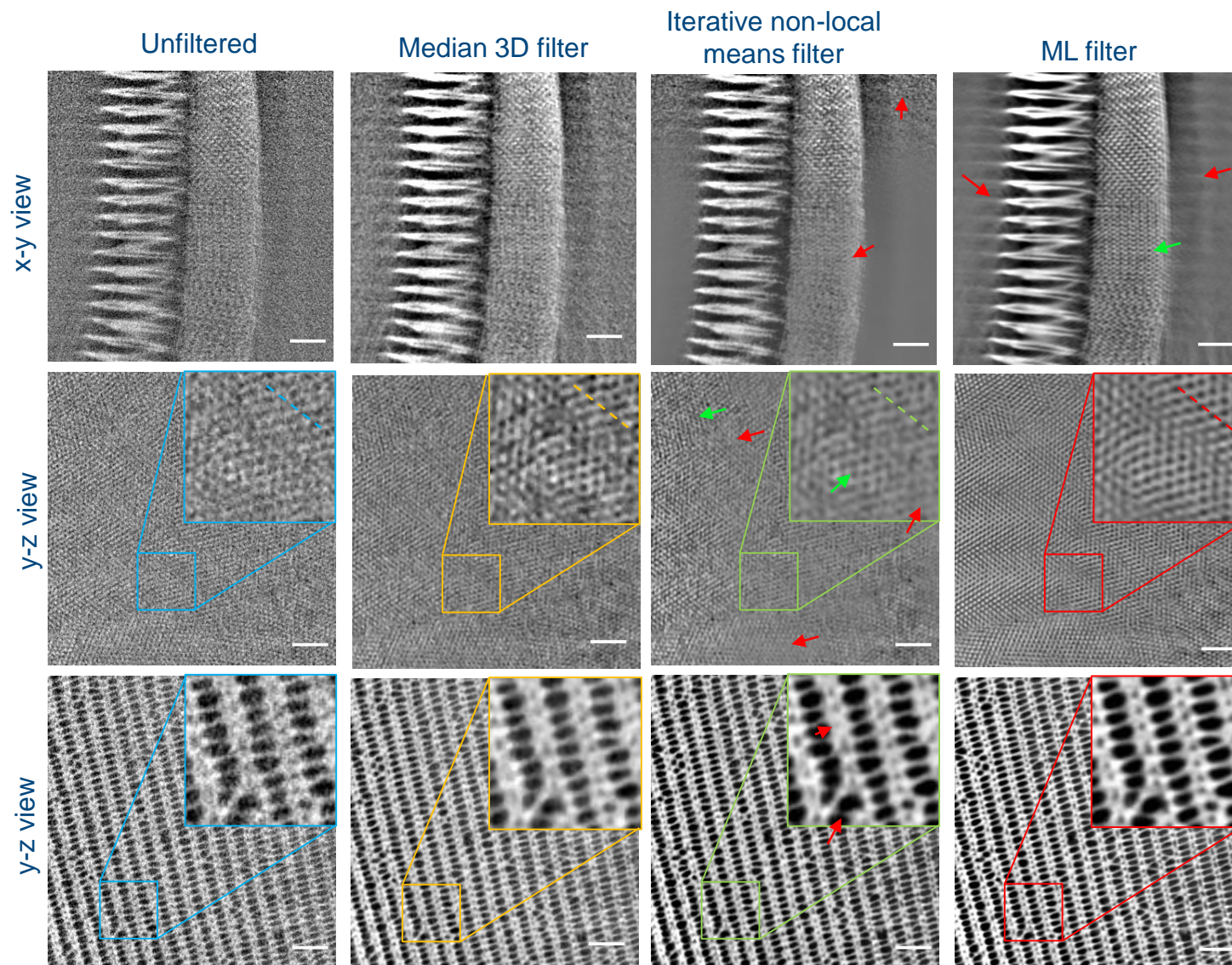
Epoch 1



epoch\_0000.tiff



# Comparison of different filter methods



- **ML filter outperforms standard filters**
- **Iterative non-local means filter works well for larger structures**