Energy resolved neutron imaging at n_TOF EAR2

M. Bacak, J.A. Pavon-Rodriguez, O. Aberle, O. Fjeld, M. Calviani, E. Chiaveri

CERN/n_TOF

A. Losko

TU Munich

E. Lehmann, M. Busi

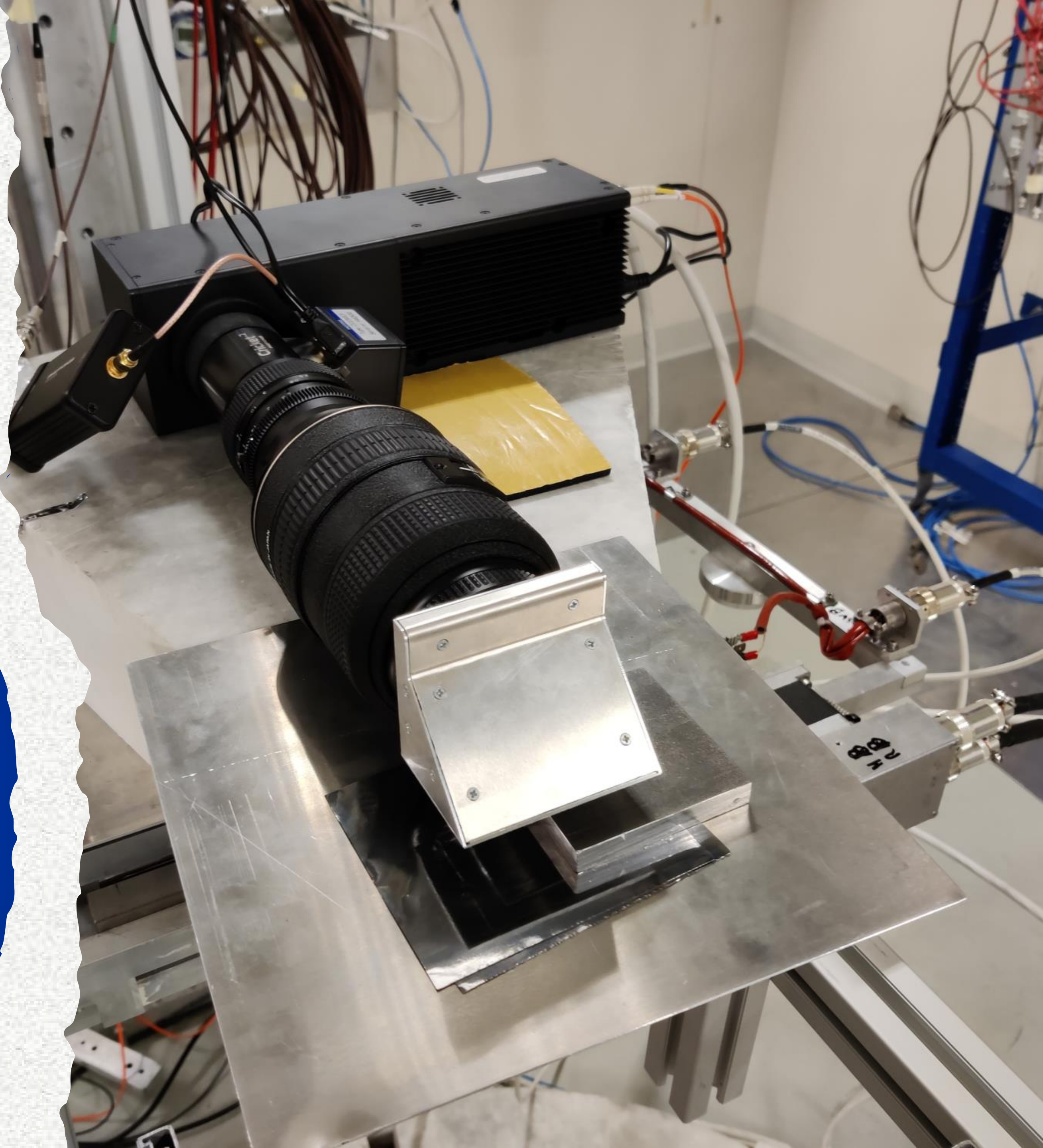
PSI

R. Beyer, A. Junghans

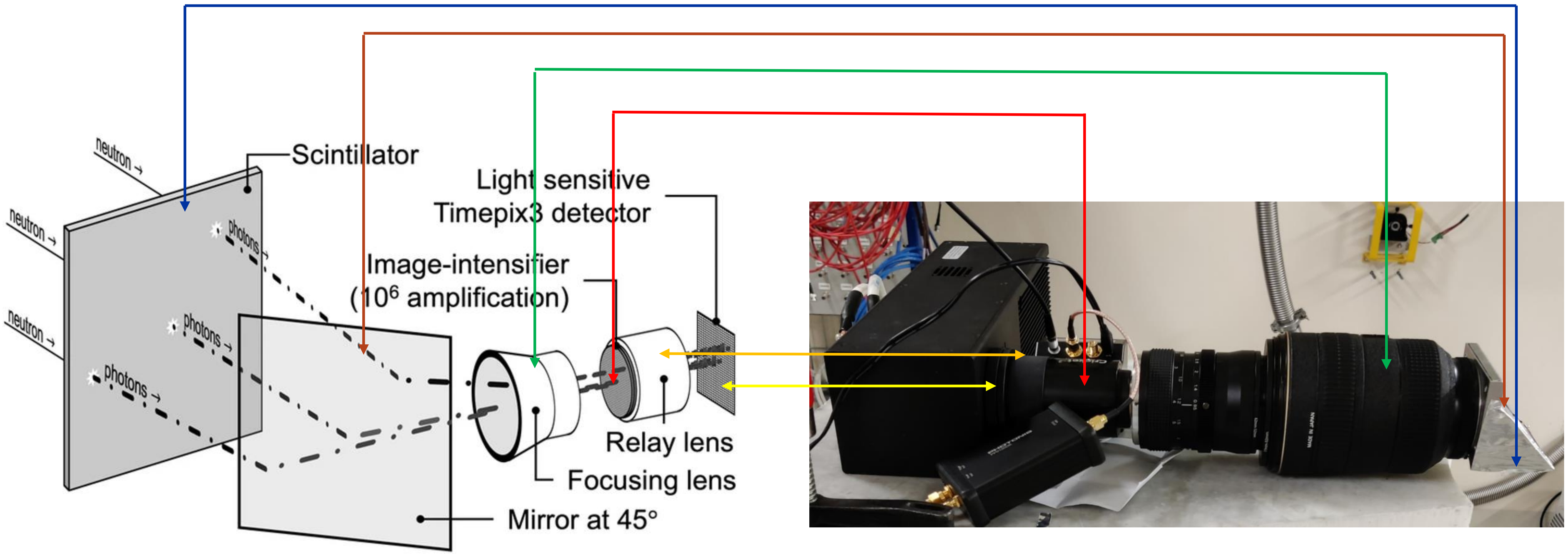
HZDR

S. Scheurren, T. Jäger

TU Darmstadt



Neutron detection in Imaging



Aim of the experimental campaign

- **The goal is to measure time-of-flight resolved neutron attenuation through matter**

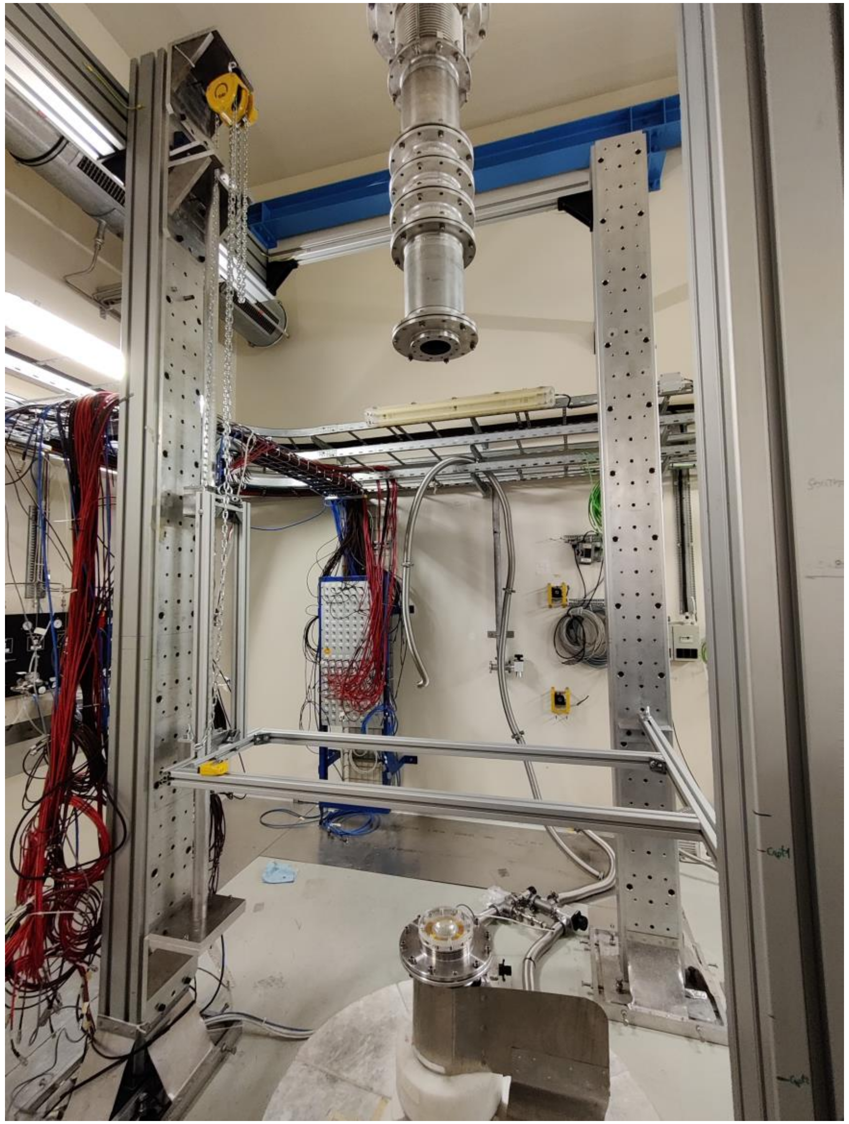
- **Proof that the technique works and can be applied at n_TOF EAR2**

- **The data should be as clean as possible to extract:**
  - Structural features (qualitative/quantitative) <<>> spatial resolution
  - Attenuation coefficients (quantitative) <<>> „neutronic“ data
  - Investigate potential material identification and contrast enhancement via resonance imaging

- **Applications**

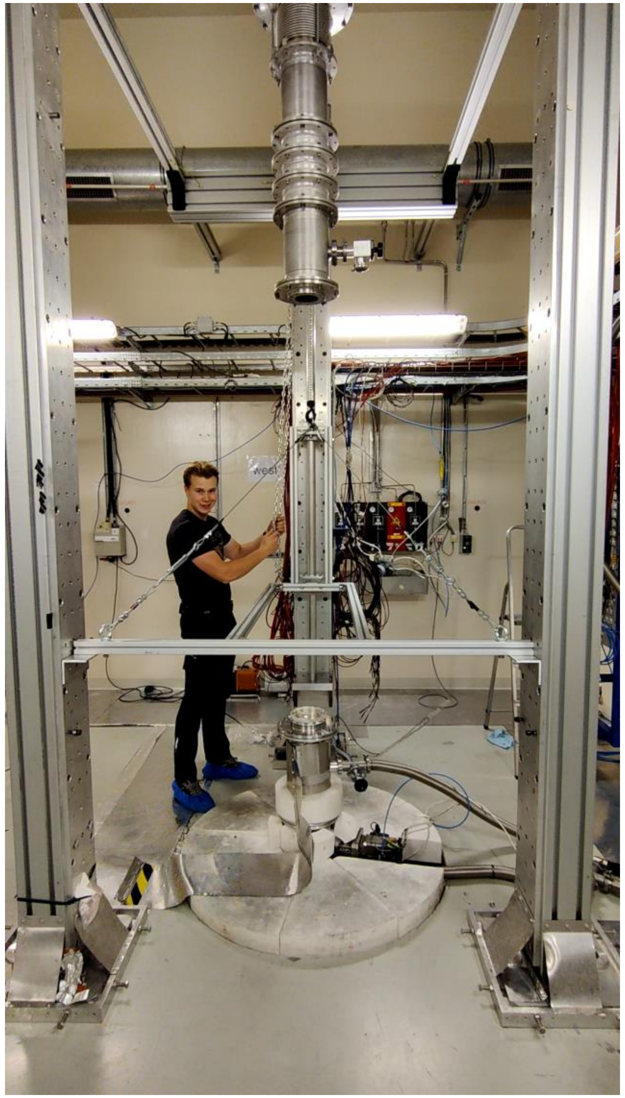
Experimental Setup(s) – lifting platform

- Several parts in this project required to move the setup along the flight path, i.e. up and down, to change instrument resolution, n/cm^2, beam profile, …
- Lifting system was designed and implemented by Oscar



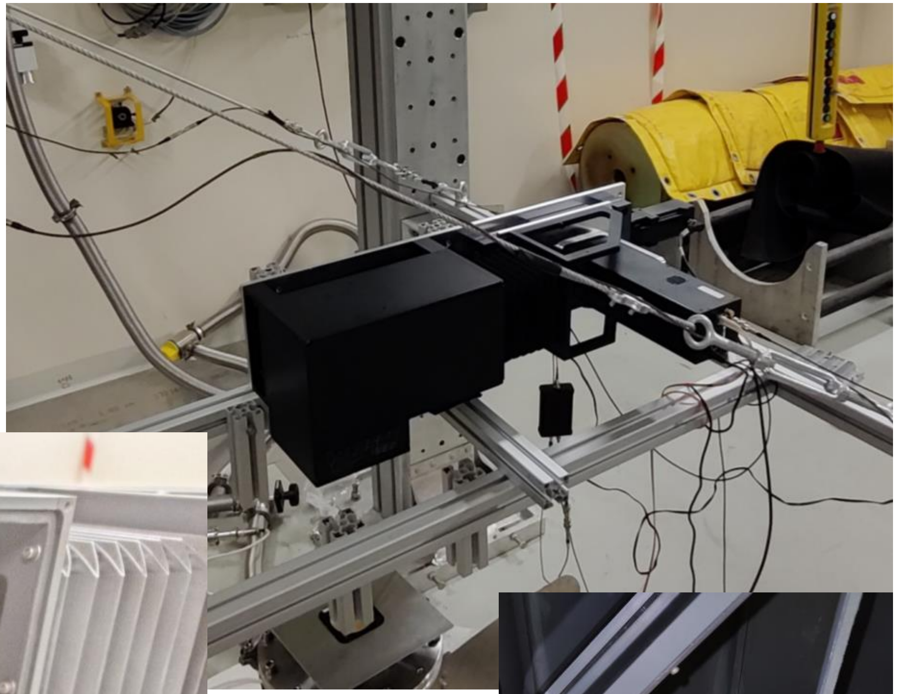
Experimental Setup(s) – lifting platform

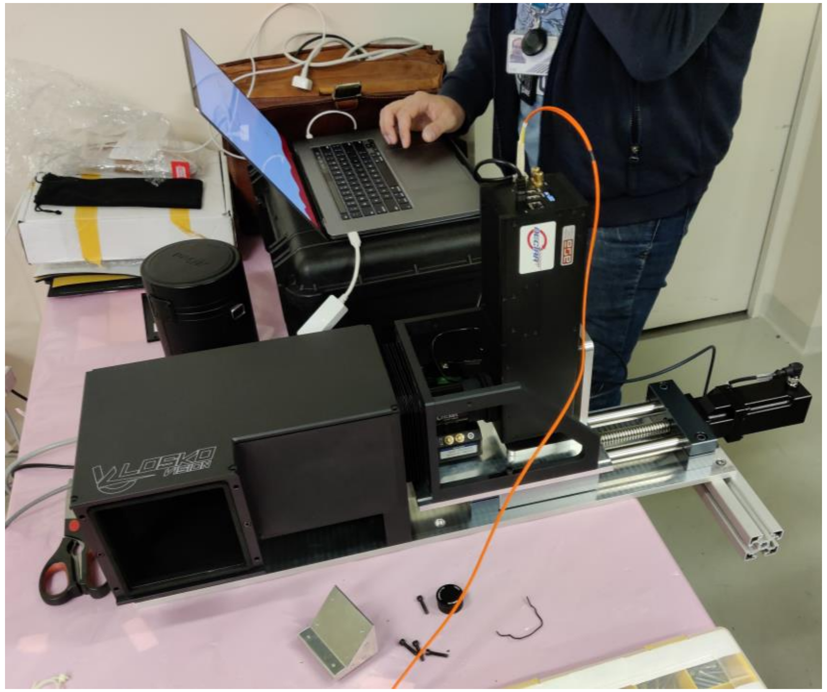
- Several parts in this project required to move the setup along the flight path, i.e. up and down, to change instrument resolution, n/cm^2, beam profile, …
- Lifting system was designed and implemented by Oscar

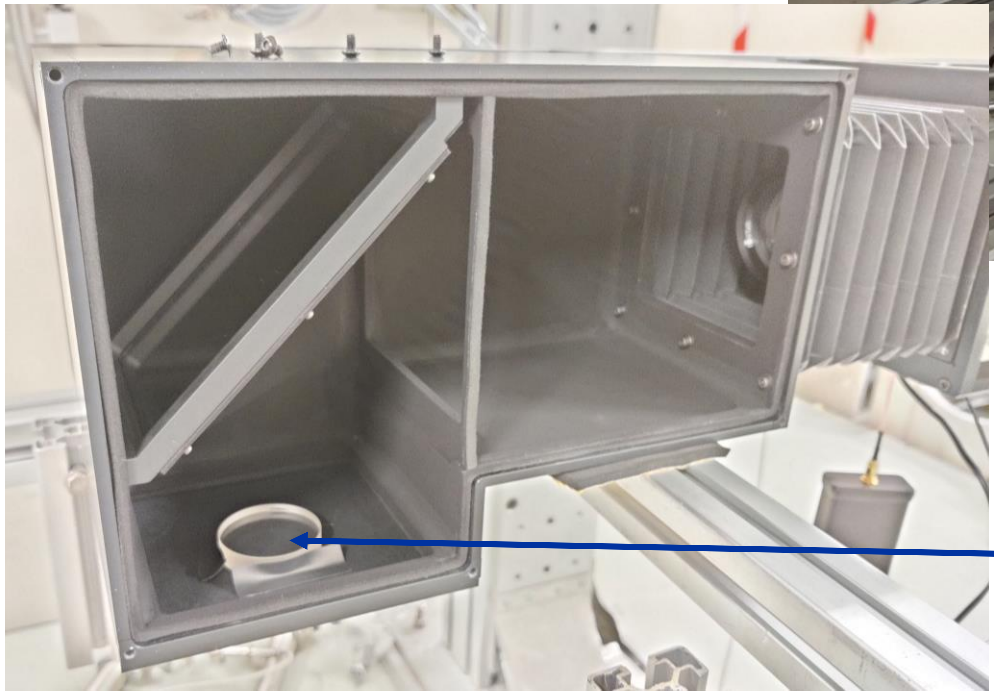


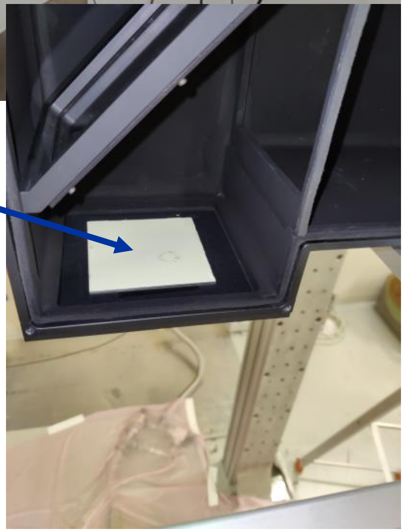
Experimental Setup(s) – macro setup (box)

- Vantablack coated (inside) aluminium box
- Max 120x120 mm^2 scintillator inside
- Optics for photography







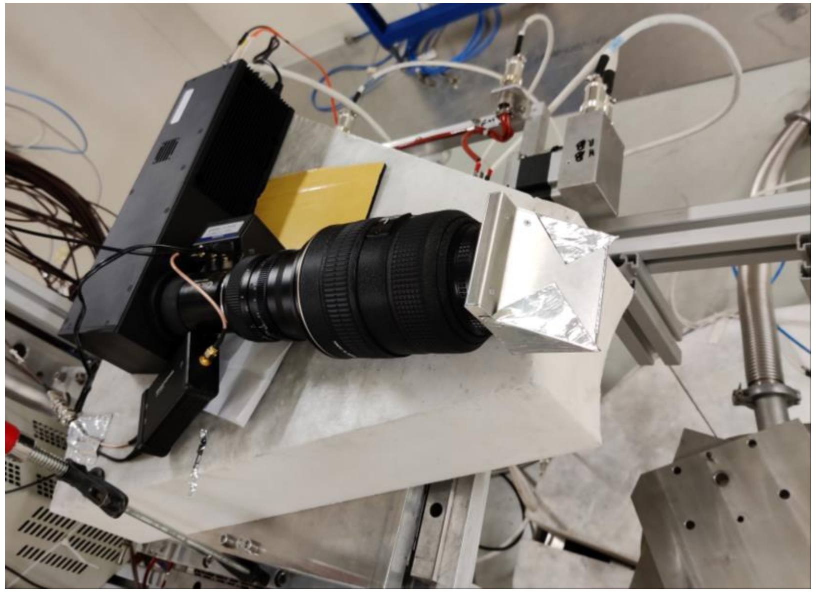


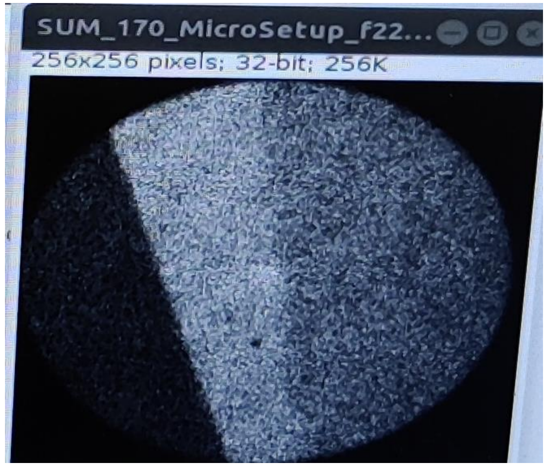
Experimental Setup(s) – micro setup (triangle)

- **Setup for high resolution measurements by focussing on a very small (30x30 mm^2) Field of View (FoV)**

- **Allows more light/cm2 → higher statistics**

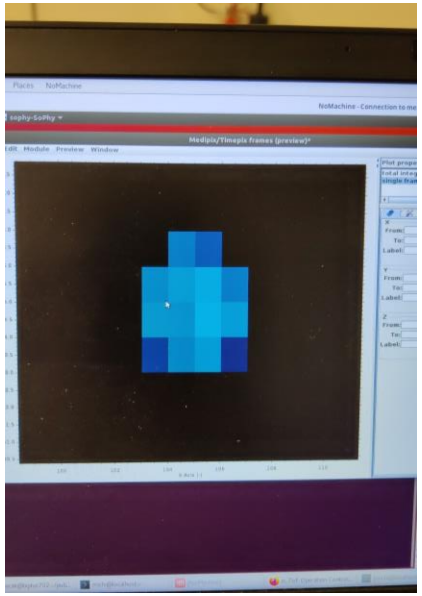
- **Single particle events spread out over more pixels,
→ enhancement of the event discrimination capability**

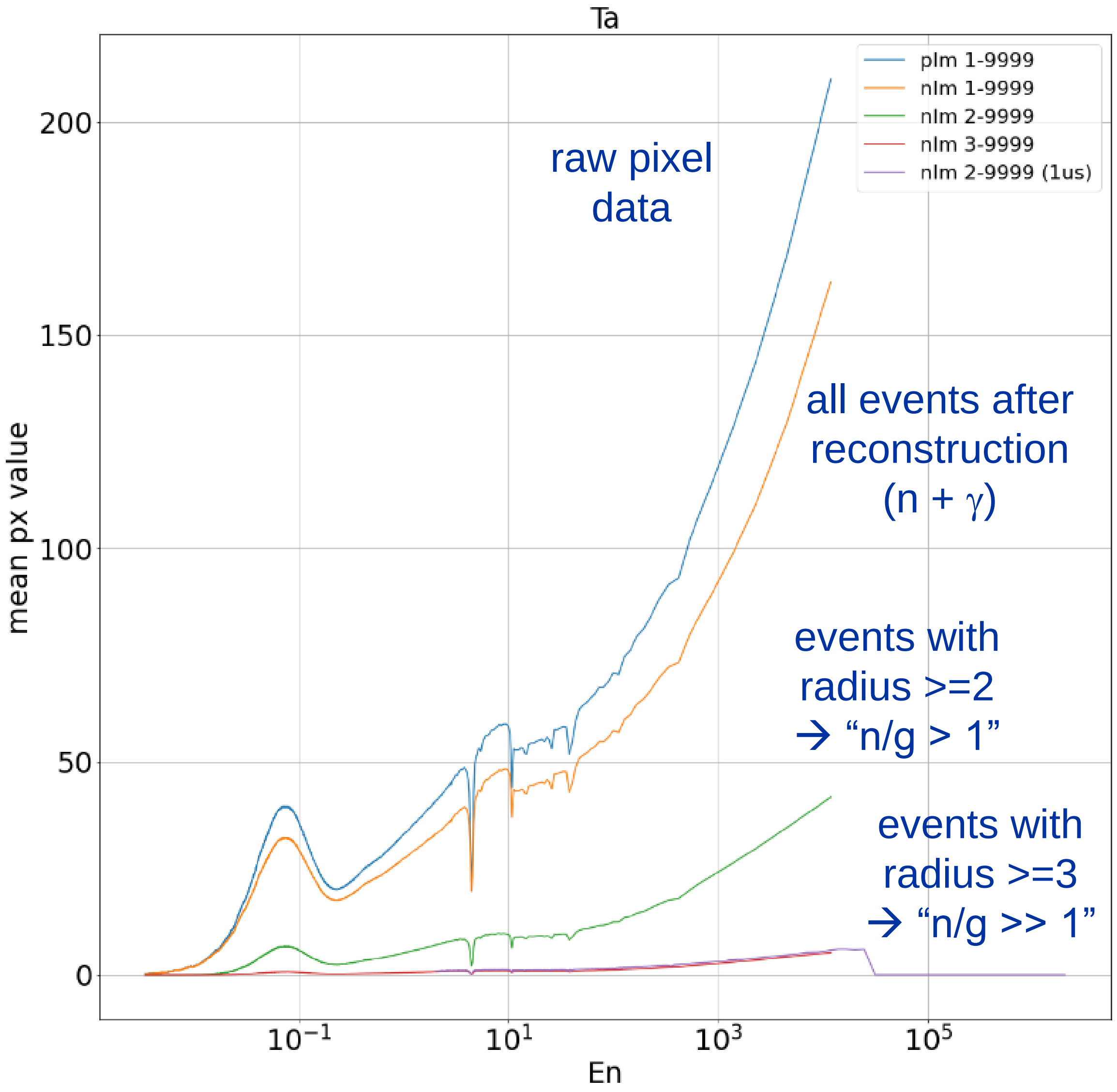




Technique – works @ n_TOF

- **3D clustering single-particle events in space (pixelized) and time (TimePix3)**
  - Subpixel resolution with Center of Mass (CoM) algorithms (requires particle scoring)
  - Time windows corresponding to the decay characteristics of the scintillators
  - Different particles (n vs. γ) produce different signatures (size/time)

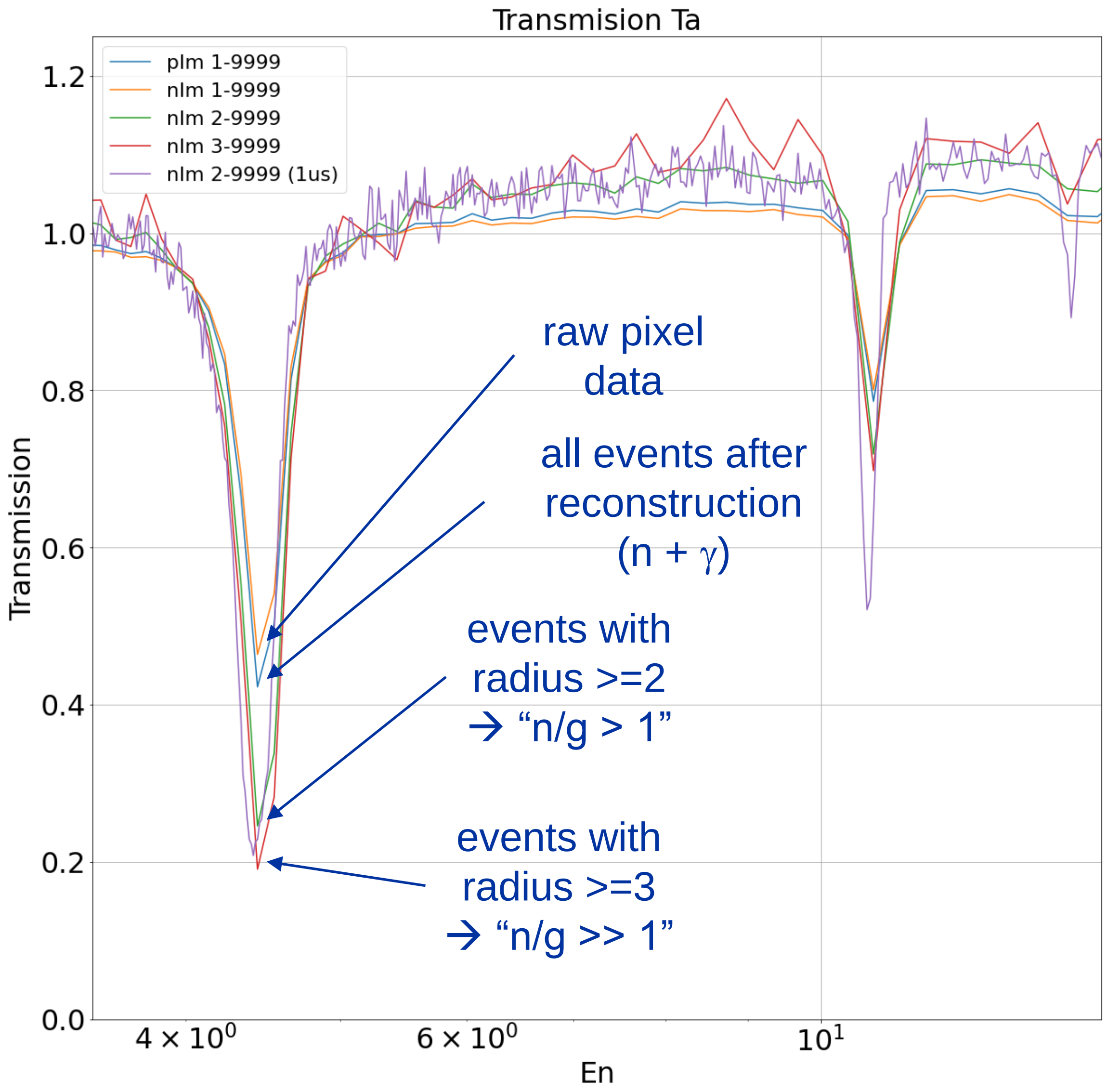




Technique – works @ n_TOF

- **3D clustering single-particle events in space (pixelized) and time (TimePix3)**
  - Subpixel resolution with Center of Mass (CoM) algorithms (requires particle scoring)
  - Time windows corresponding to the decay characteristics of the scintillators
  - Different particles (n vs. γ) produce different signatures (size/time)

- **This allows to remove background leaving only „neutron data“**
  - Visible in the transmission spectra, as attenuation behaviour (i.e. dips) gets cleaner the more „neutronic“ the data becomes

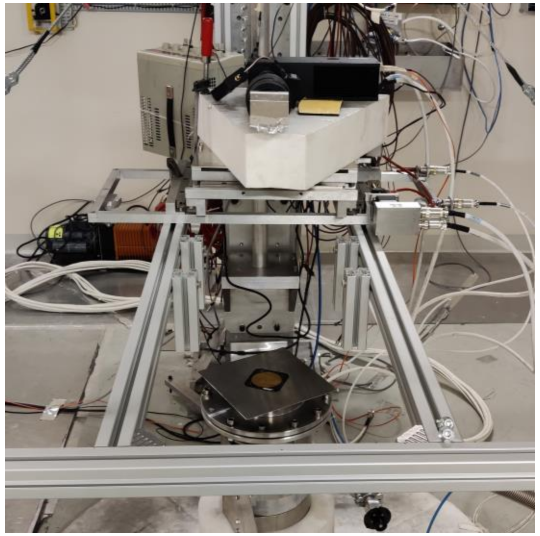


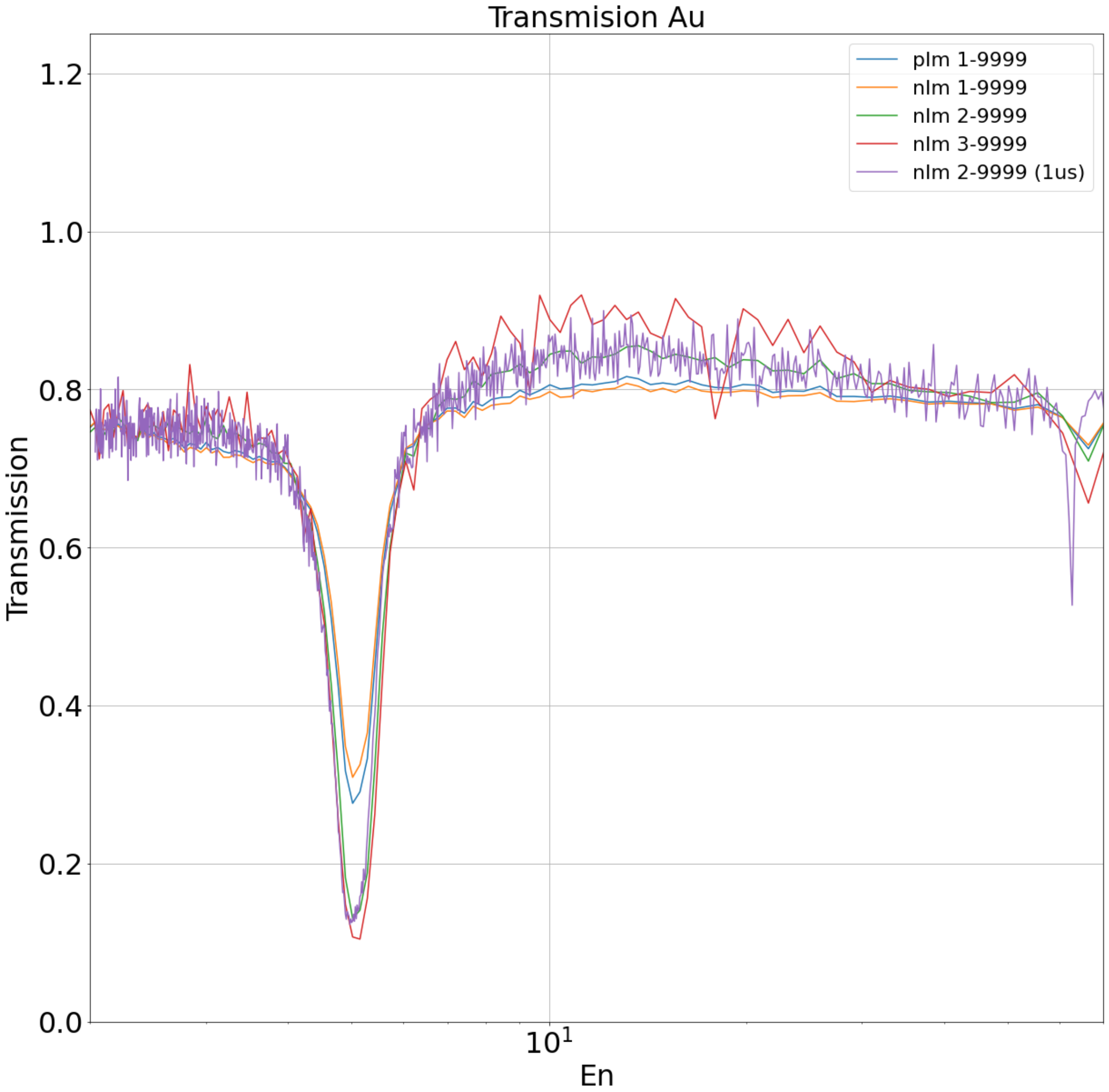
Resonances

- **Measured available materials with known resonances:**
  - Au 100 um
  - Co 500 um
  - Ta 50-100 um
  - Fe „resonances“ → Bragg Edges
  - Various filters: W, Mo, Cd, … (not shown)

Resonances – Au

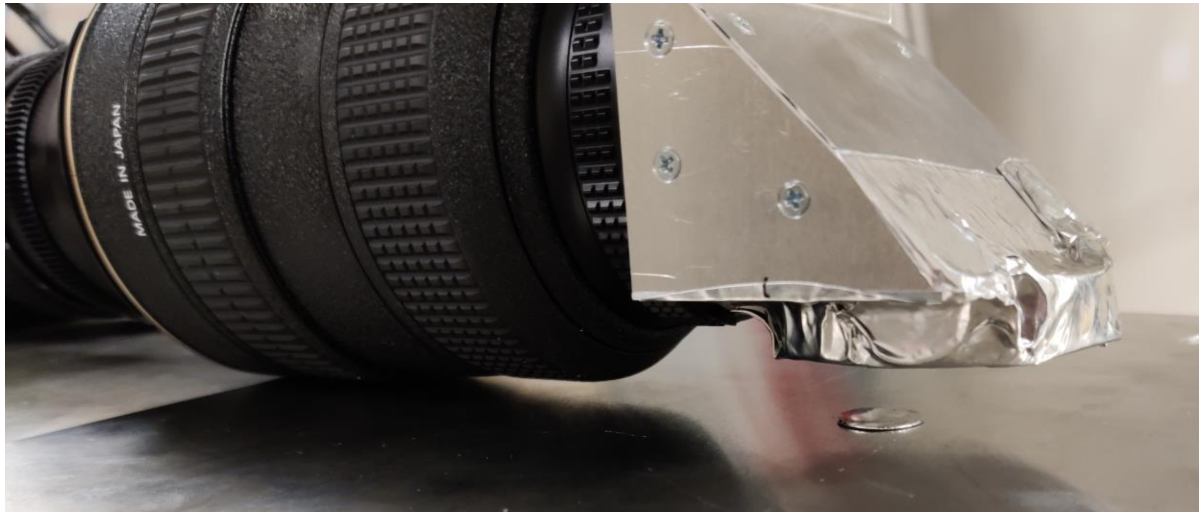
- **Measured available materials with known resonances:**
  - **Au 100 um**
  - Co 500 um
  - Ta 50-100 um
  - Fe „resonances“ → Bragg Edges
  - Various filters: W, Mo, Cd, … (not shown)

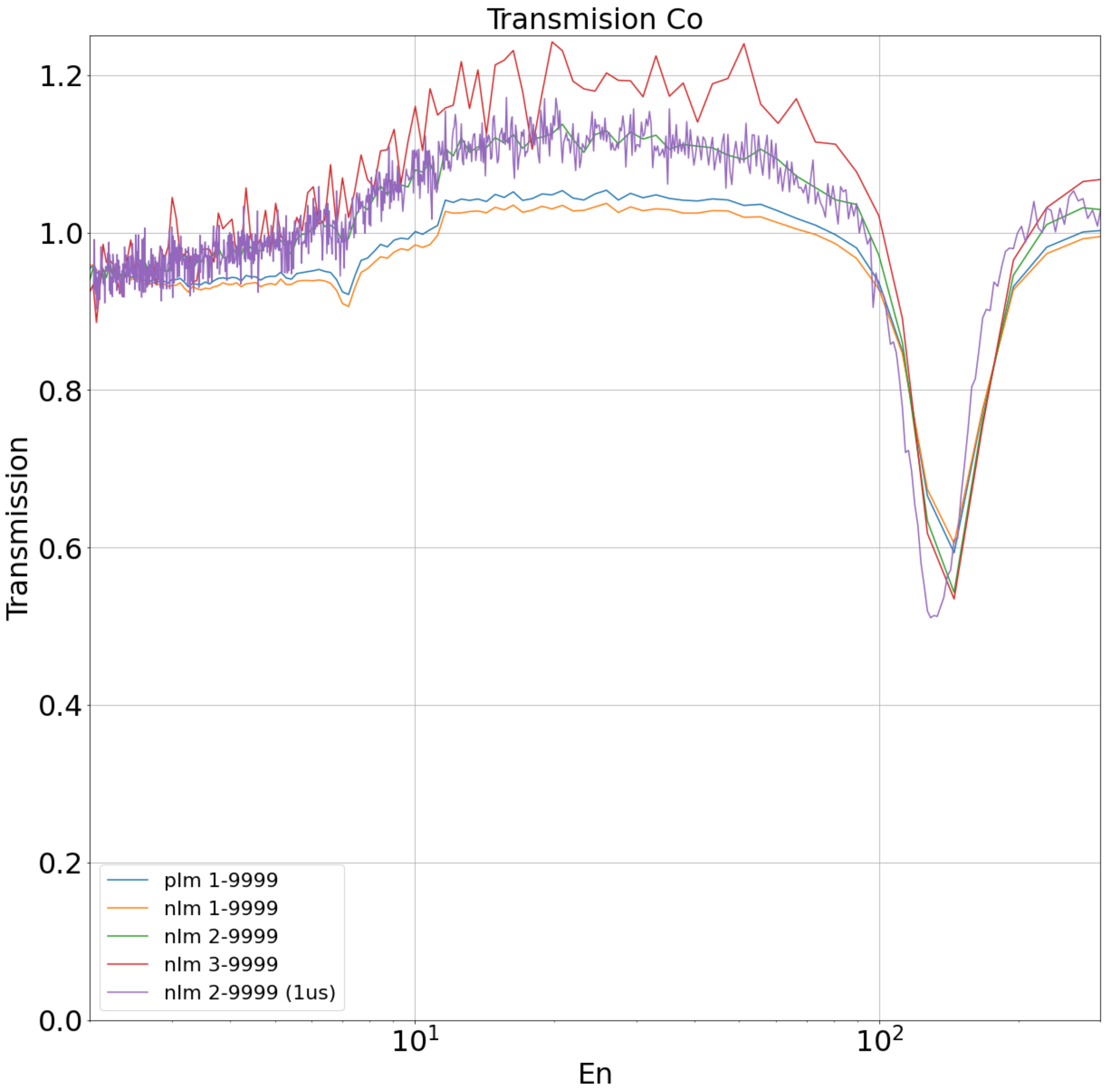




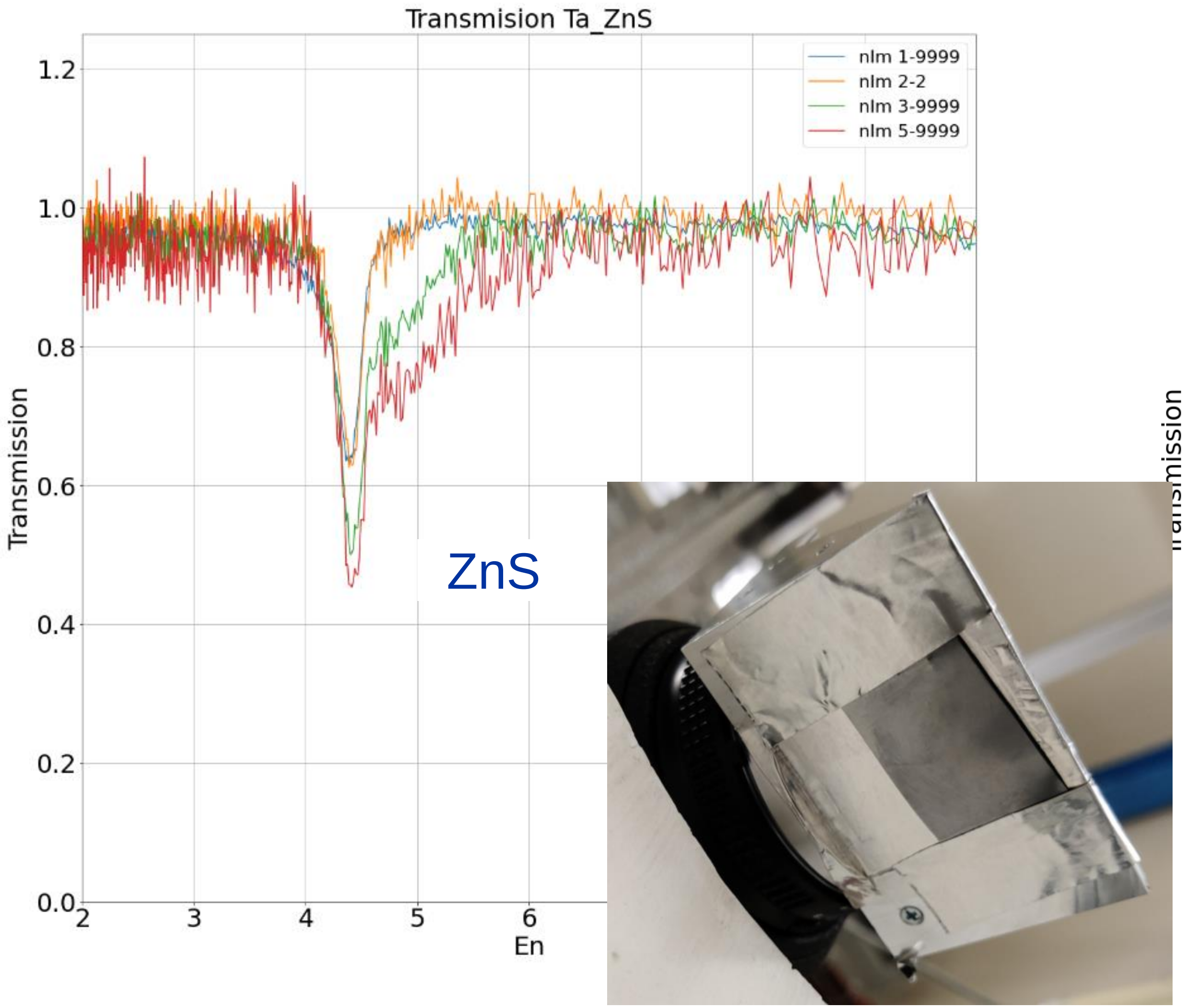
Resonances – Co

- **Measured available materials with known resonances:**
  - Au 100 um
  - **Co 500 um**
  - Ta 50-100 um
  - Fe „resonances“ → Bragg Edges
  - Various filters: W, Mo, Cd, … (not shown)

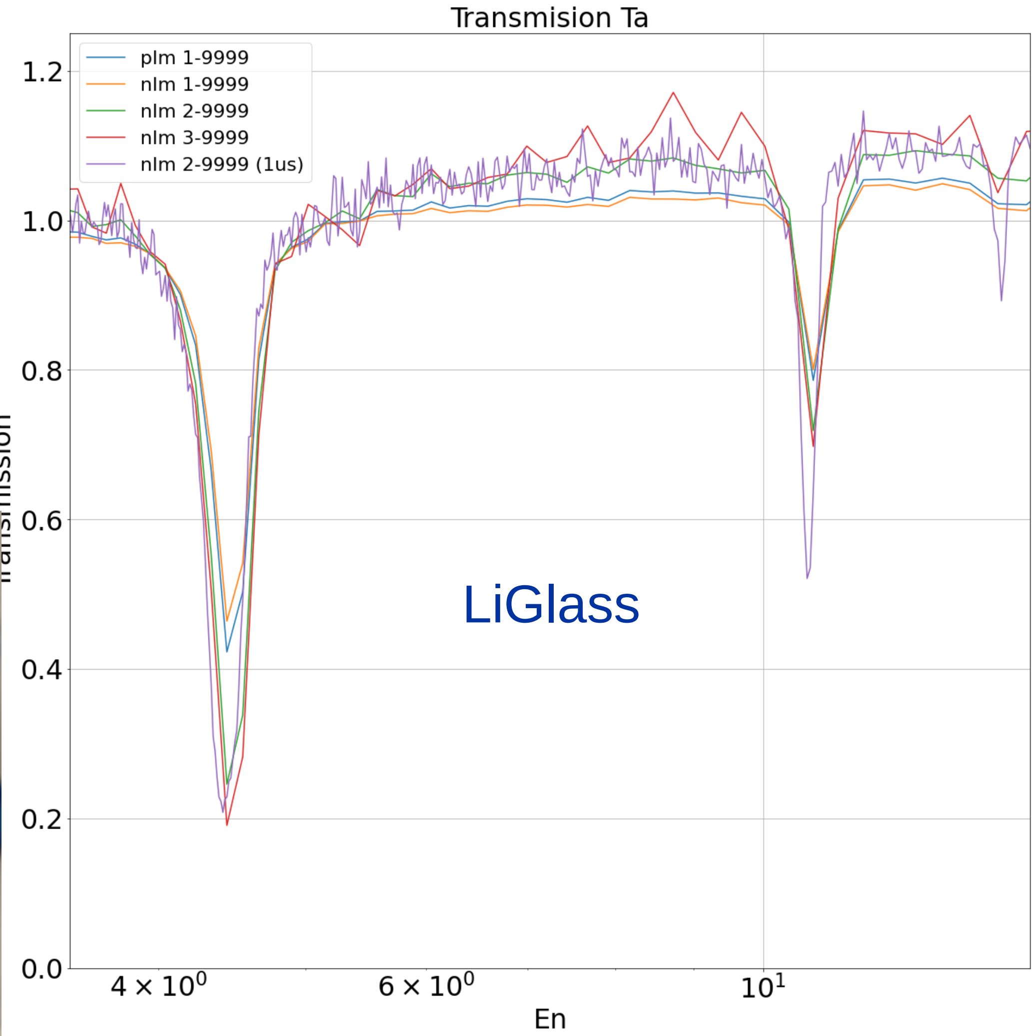




Resonances – Tantalum (ZnS vs. LiGlass)



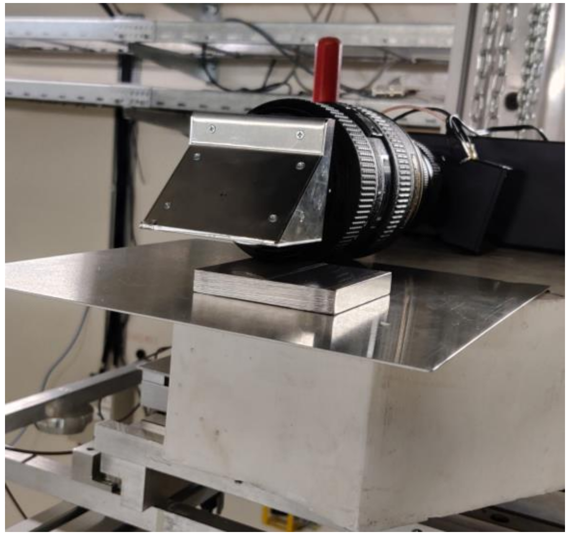
ZnS

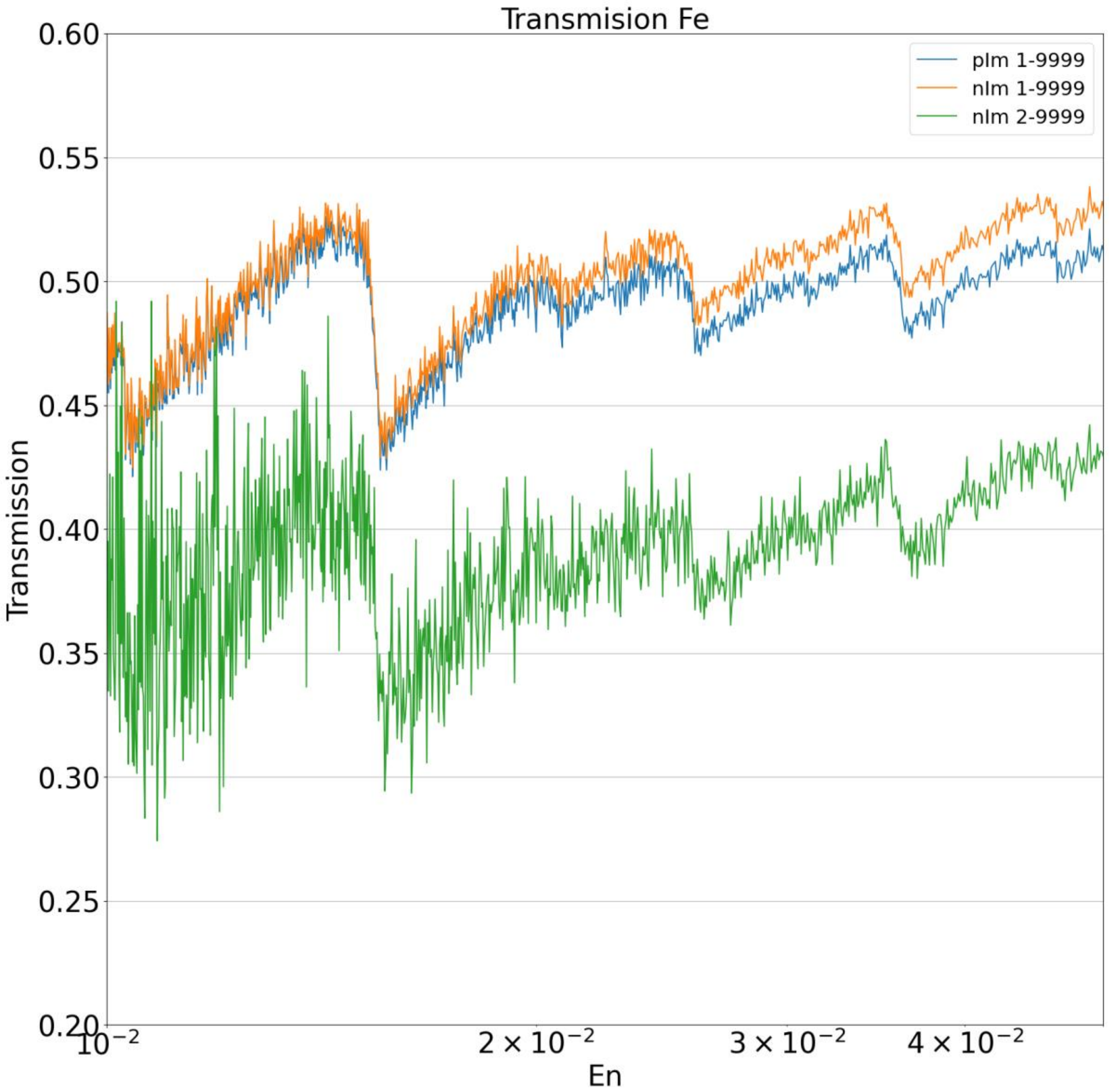


LiGlass

Resonances – Co

- **Measured available materials with known resonances:**
  - Au 100 um
  - Co 500 um
  - Ta 50-100 um
  - **Fe „resonances“ → Bragg Edges**
  - Various filters: W, Mo, Cd, … (not shown)

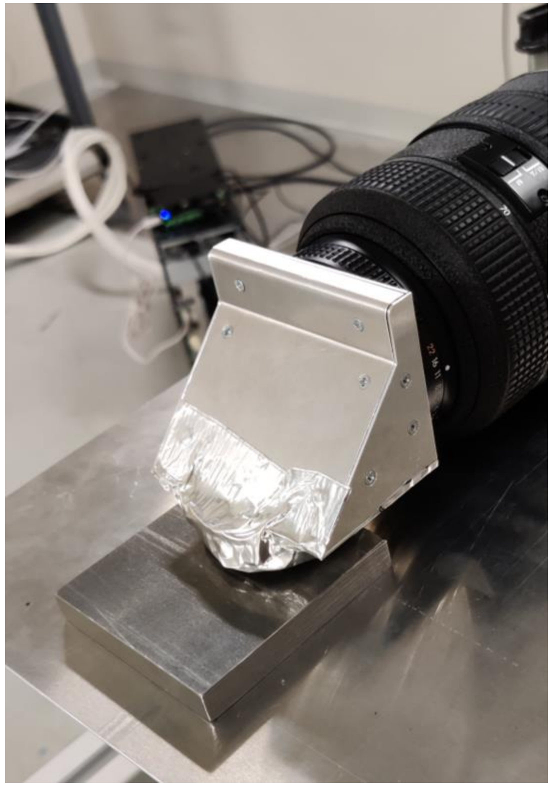


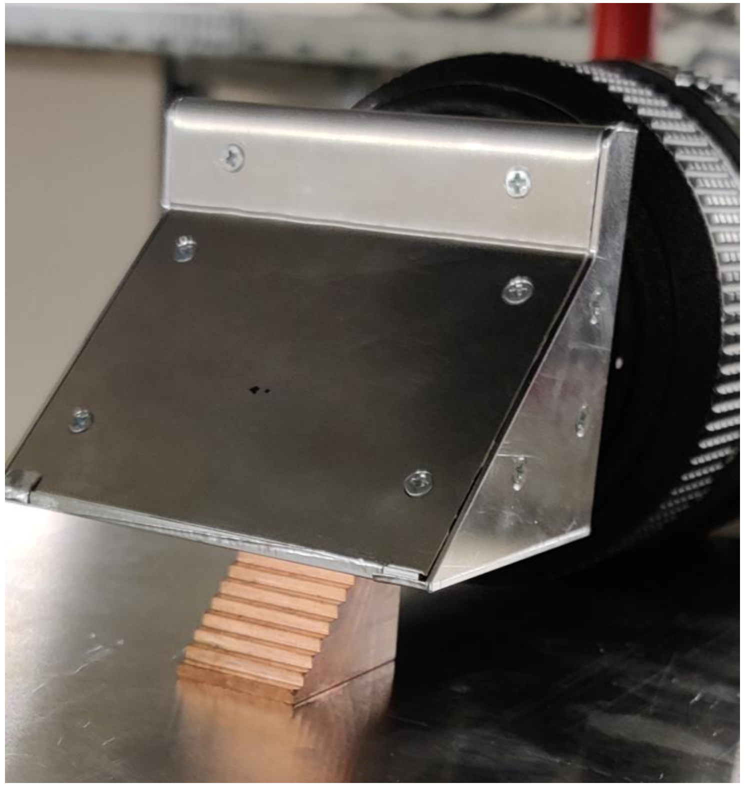


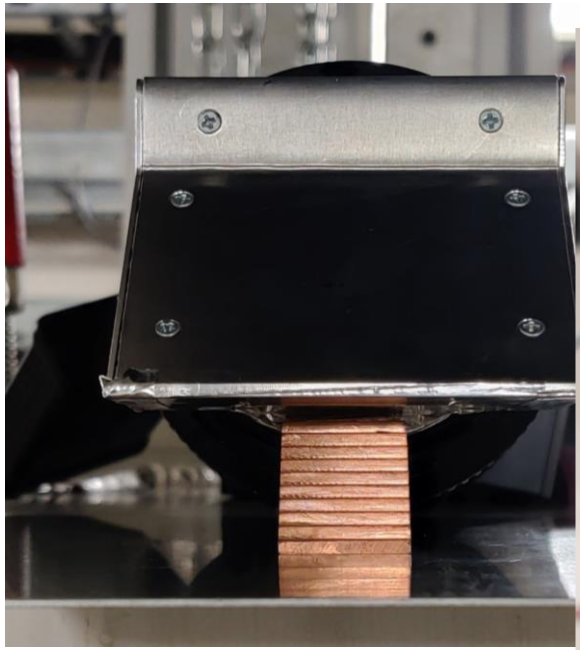
Spatial resolution

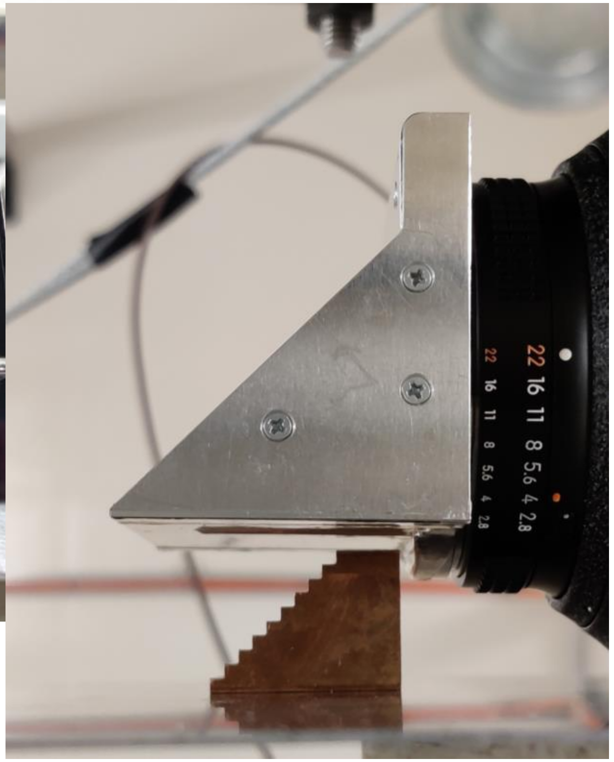
- **Measure a clean geometrical edge to determine the spatial resolution**

- **In this case copper step wedge (2 mm per step)**



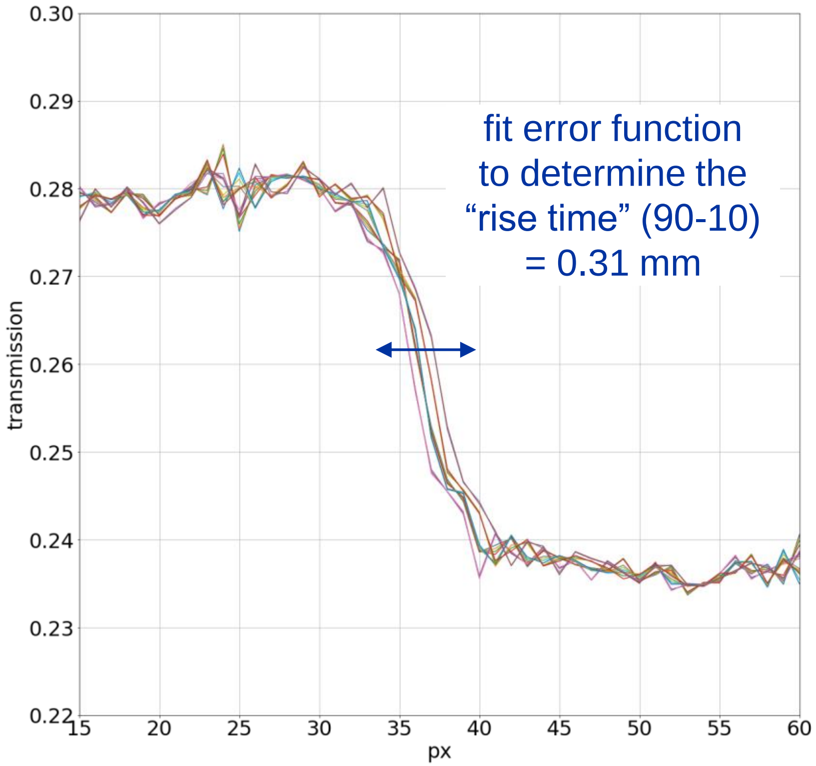


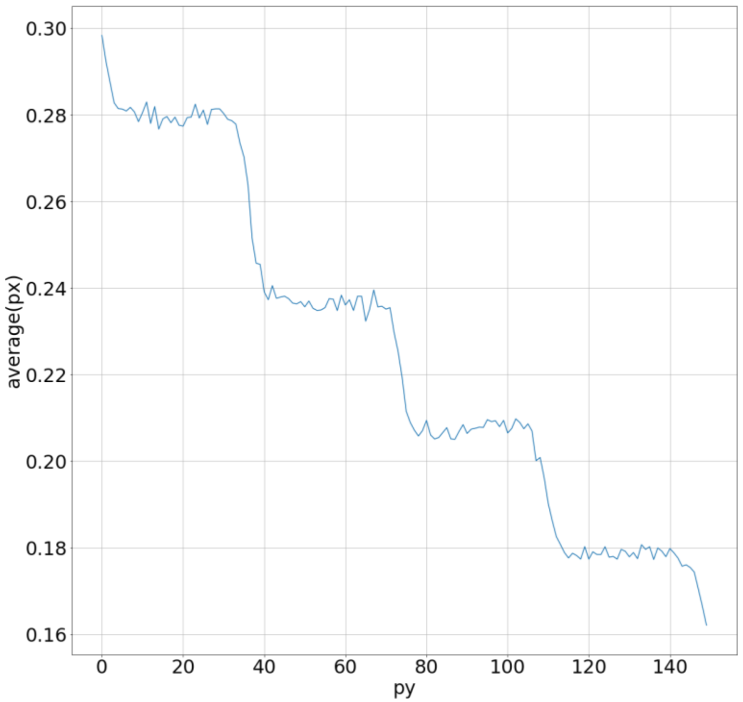


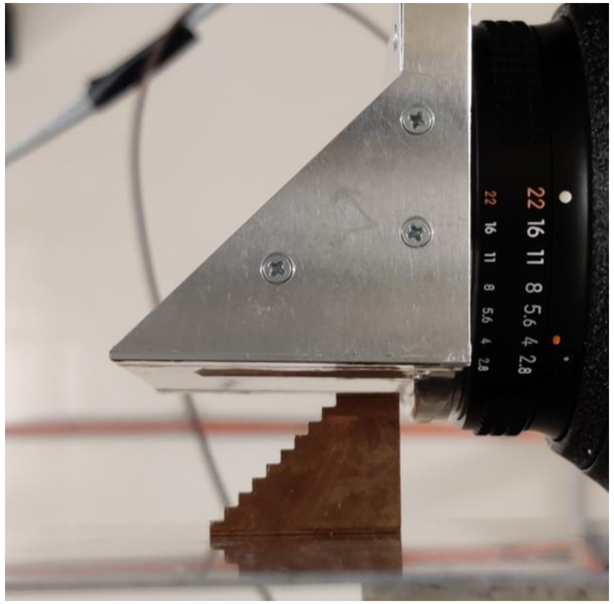


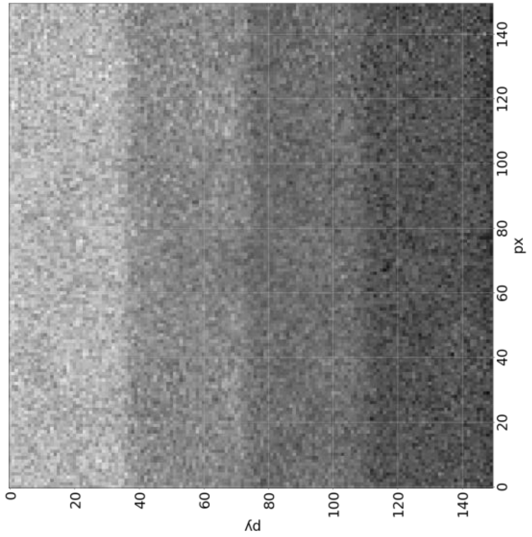
Spatial resolution – Cu step wedge

- Measure a clean geometrical edge to determine the spatial resolution
- In this case copper step wedge (2 mm per step)



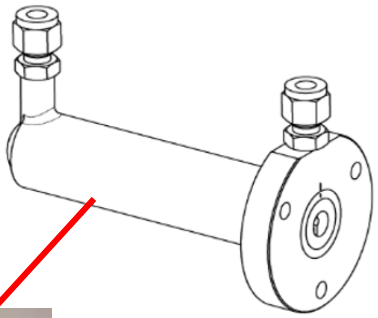


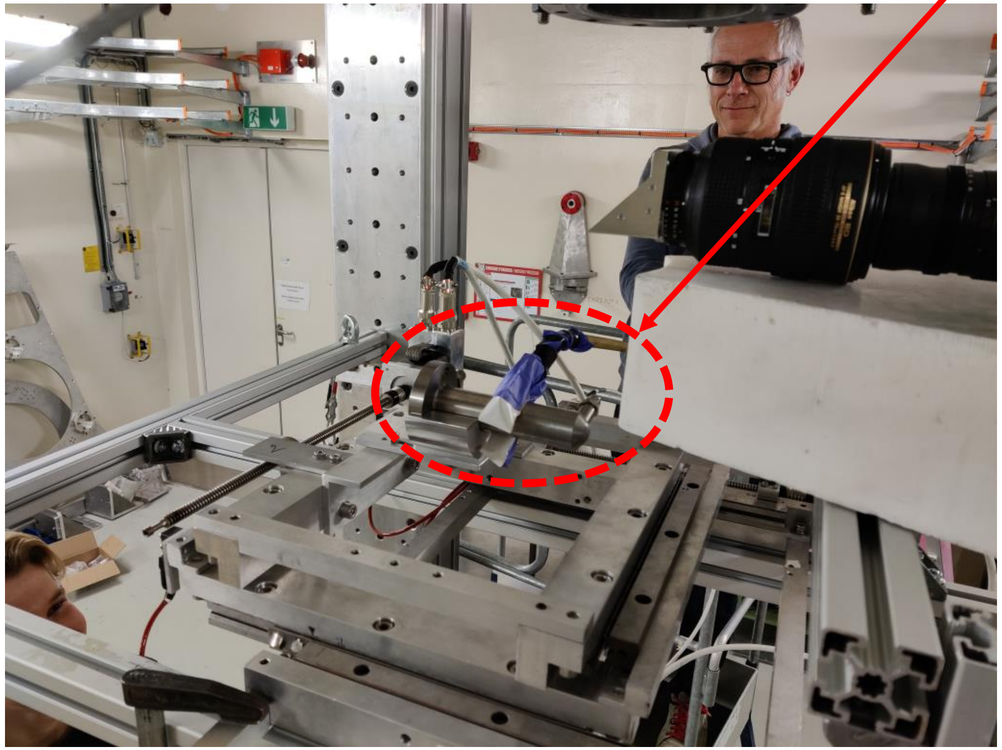


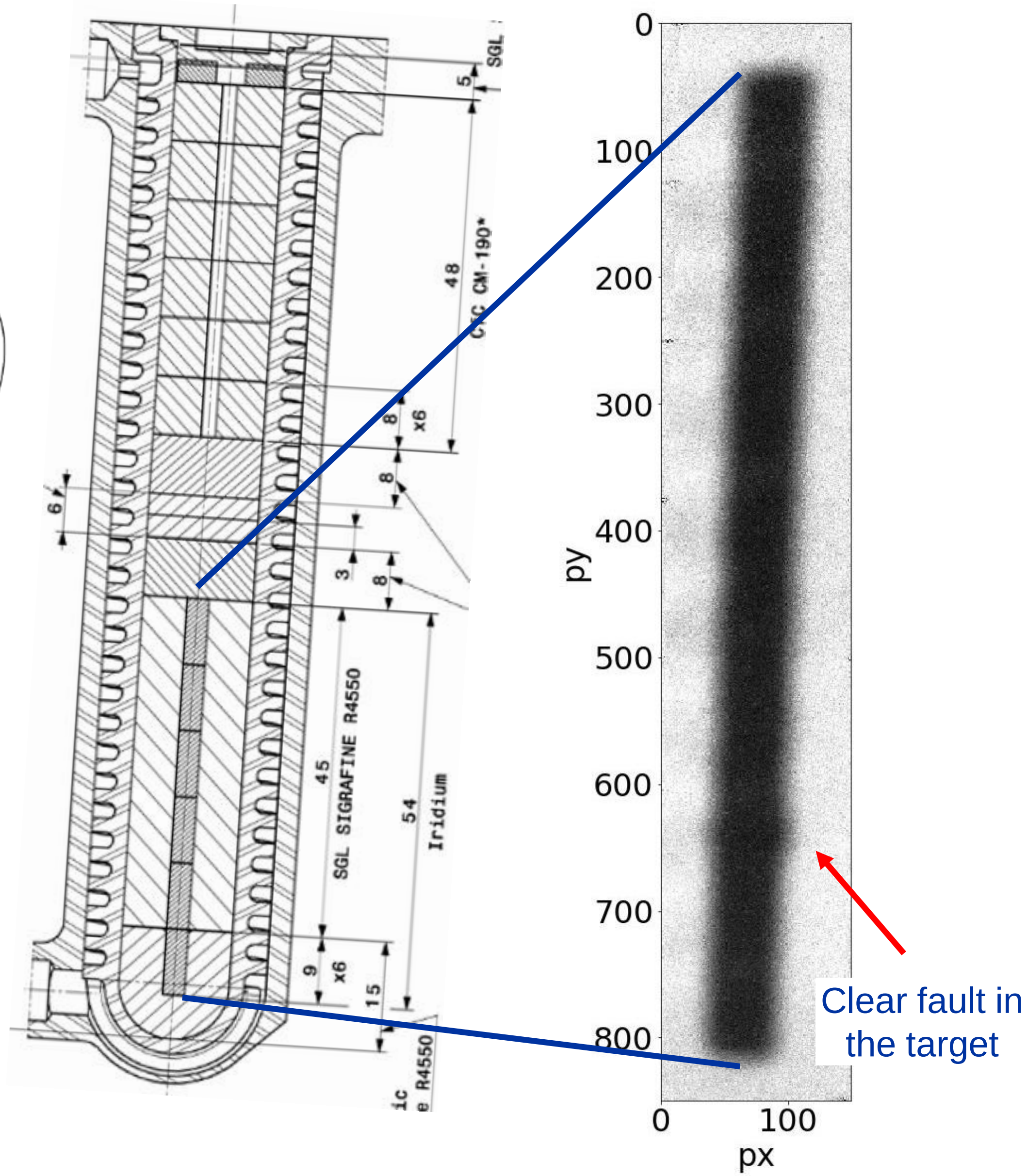


Applications: AD-Target

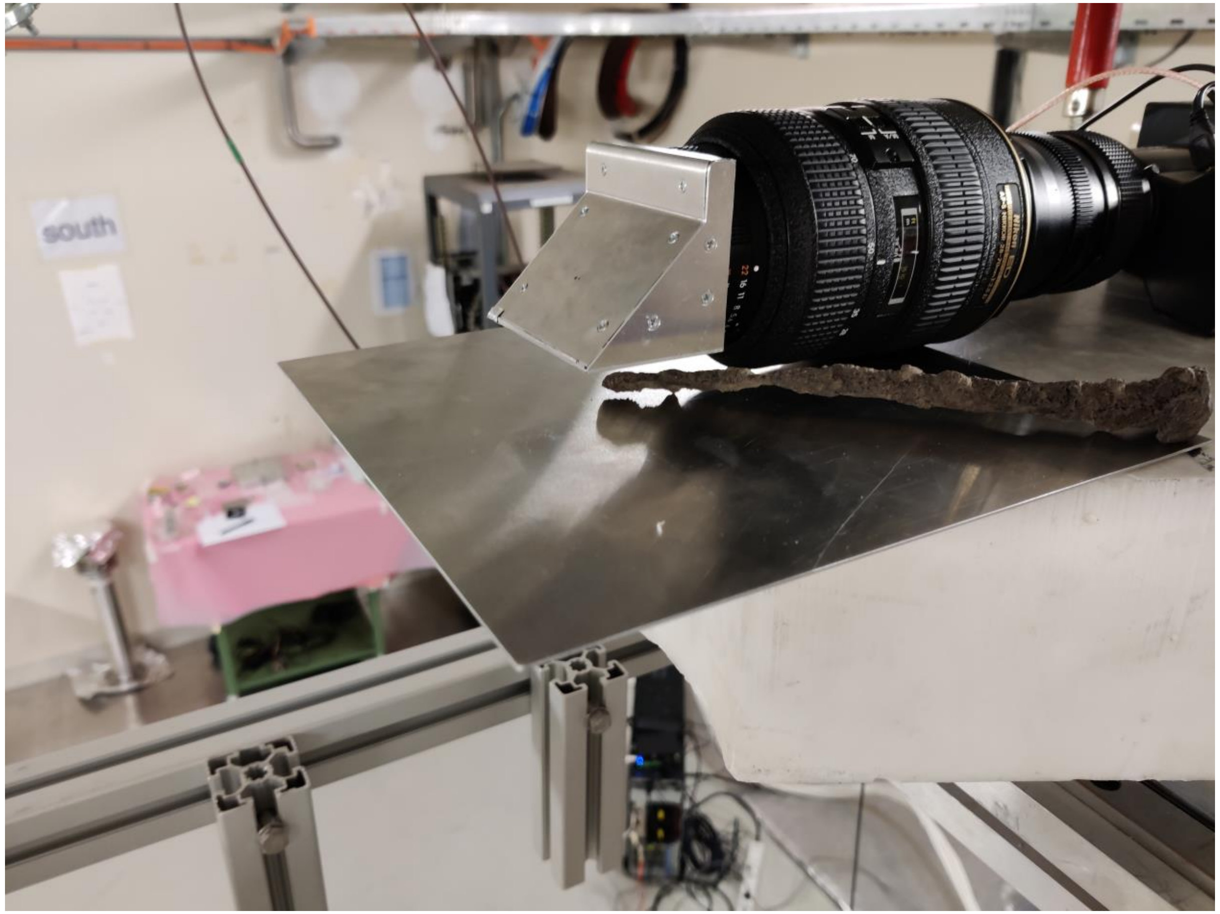
- Irradiated and fresh AD-Target
- Scan of 55 mm Iridium pin with a FoV of 12 mm + image stitching





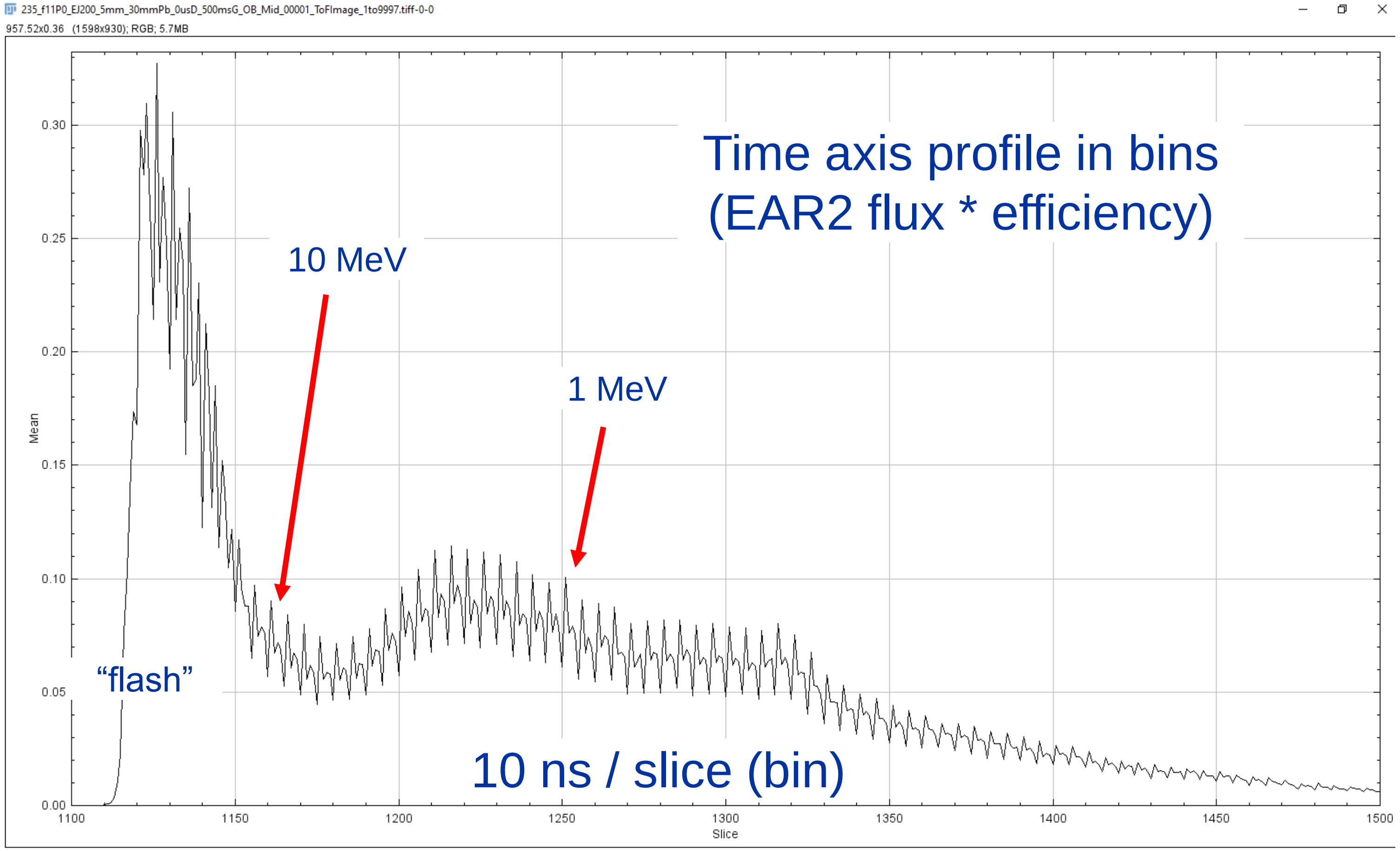


Applications: cultural heritage – Roman nail



Applications: beam profiles

- **Data available for:**
  - <0.01 – 100 eV (ZnS:Ag/^{6}LiF)
  - 1 – 10 MeV (EJ200)
- **We know the absolute position of the detector, hence the beam position, thanks to CERN Survey (Dirk) and can correct for that in the images**
- **No time to analyze the data yet**
- **Issues:**
  - Oscillations are most likely a firmware problem on the chip/FPGA level
  - Just affecting the precision/binning – the data/time-stamping is correct



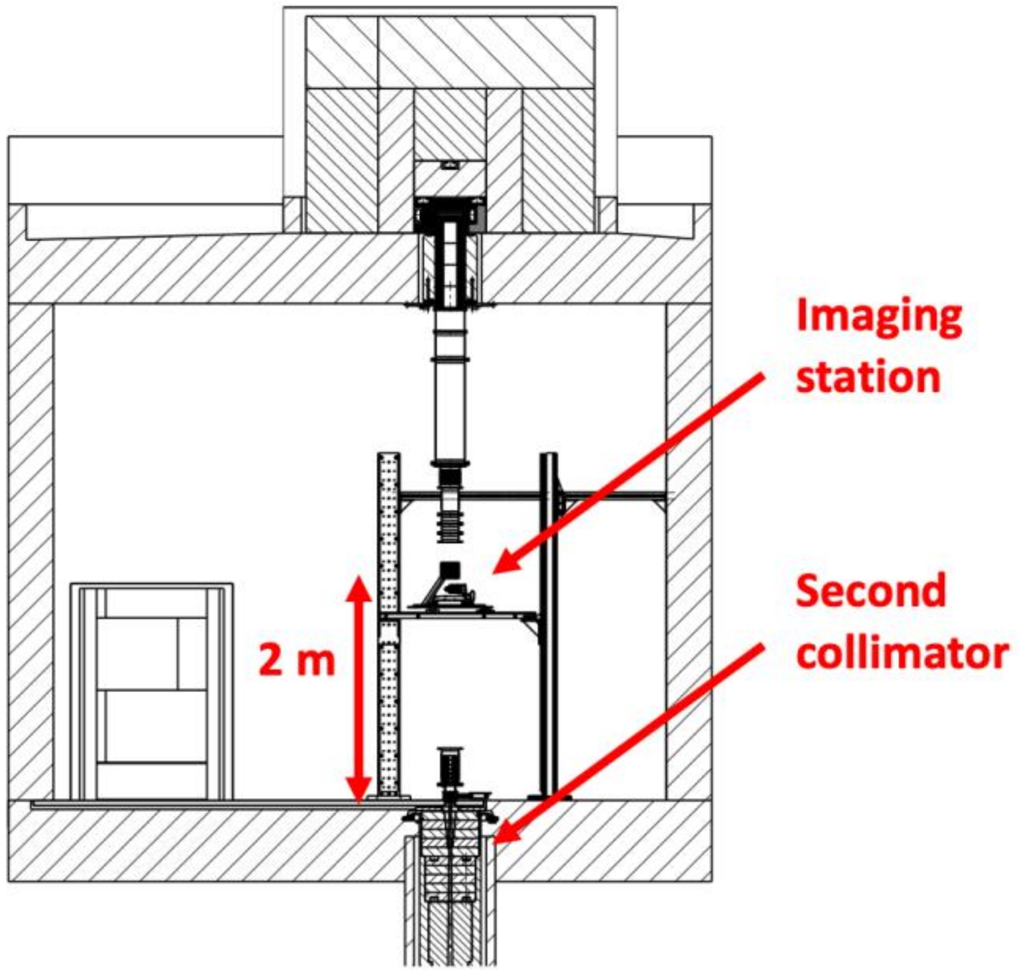
Conclusions & Outlook

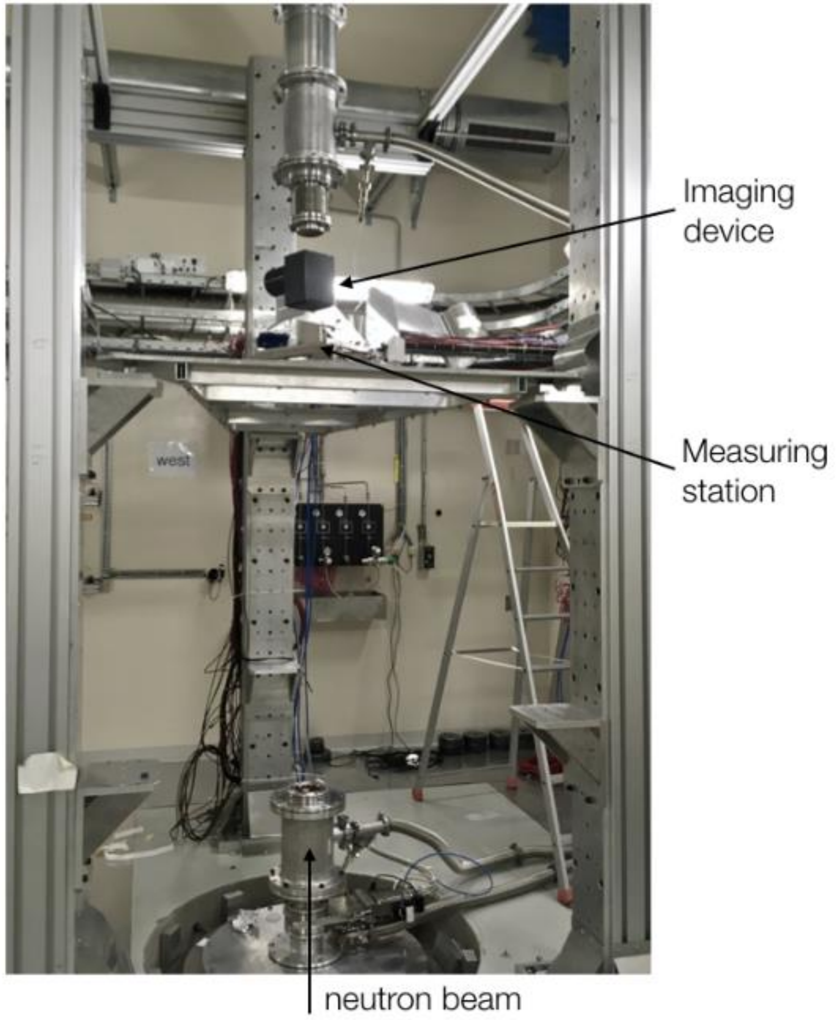
- **Time resolved neutron imaging based on TimePix3 camera works at n_TOF EAR2**
- **With some limitations:**
  - Instantaneous neutron flux / high count rate blinds the image intensifier / issues with event reconstruction
  - For imaging applications the resolution might be too bad and the flux/s too low
- **Nevertheless:**
  - The count rate limitation might be resolvable – image intensifier technology for high rate applications under development + Quad-TimePix
  - The time structure (high, intermediate and cold spectrum) of the neutron beam is very interesting for detector development, resonance imaging, bragg edge imaging (tbc)
- **Big thanks @ sample/scintillator providers (Roland, Arnd, Matteo & Eberhard),**
  stor takk @ Oscar,
  riesen Dankeschoen @ Oliver,
  muchas gracias @ Jose

Thanks!

Michael Bacak
michael.bacak@cern.ch

Review: Imaging 2015-2018 – setup





Review: Imaging 2015-2018 – setup (zoom)

- **Detection system from Photonic Science:**
  - ZnS/6LiF based neutron scintillator (100×100 mm^2, 100 μm)
  - Air-cooled SCMOS camera 2k×2k @ ½ inch × ½ inch
- **Auto mode or triggered by PS**