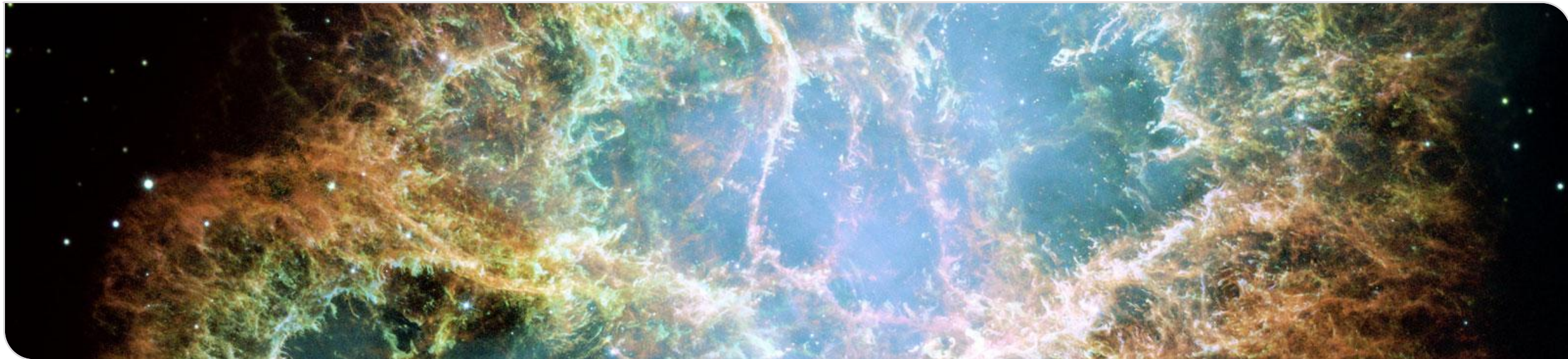


Dark Matter & Neutrinos under the Microscope at KIT

Alexey Elykov

Institute for Astroparticle Physics (IAP)



❖ **KIT is one of the major scientific research institutes in Europe**

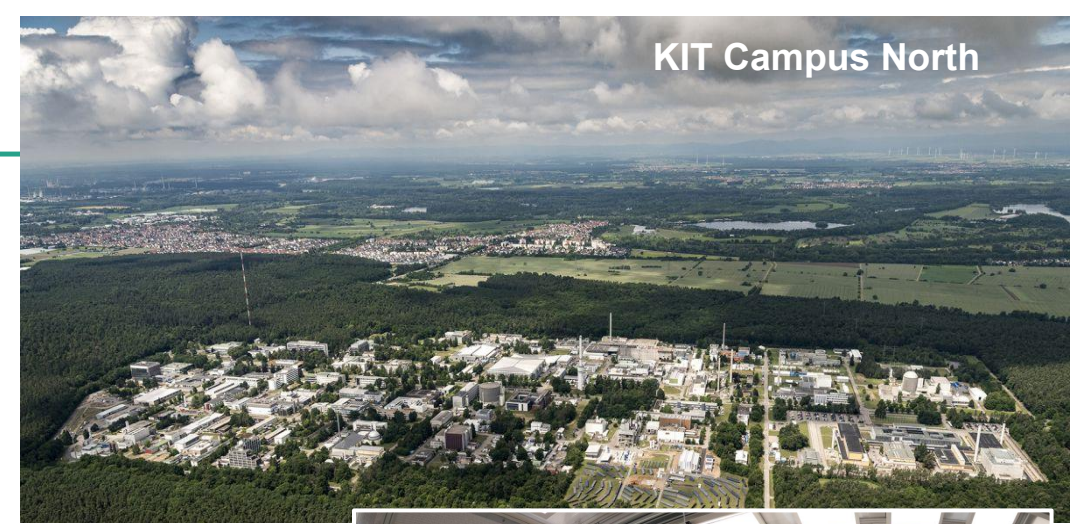
- ~9,500 scientific & other workers
- ~24,000 students on various levels

❖ **Multiple Research Topics**

- Energy, materials, information, geology ...

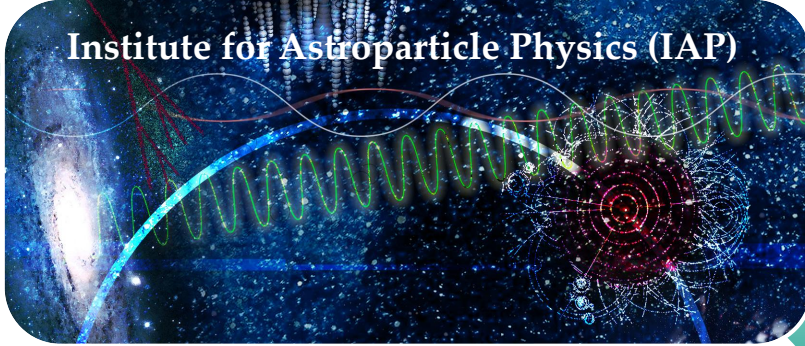
❖ **Particle & Astroparticle Physics**

- Theoretical & experimental collider/astroparticle physics
- Pierre Auger Observatory, IceCube
- XENONnT, XLZD, KATRIN
- Expertise in electronics, simulations, hardware R&D, data analysis, etc...



The Karlsruhe Institute of Technology

Institute for Astroparticle Physics (IAP)



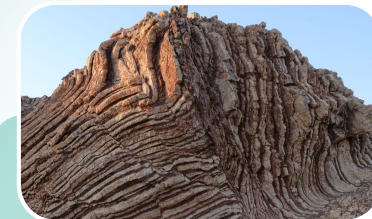
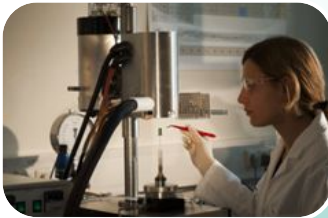
Laboratory for Electron Microscopy (LEM)



Karlsruhe Nano Micro Facility (KNMFi)



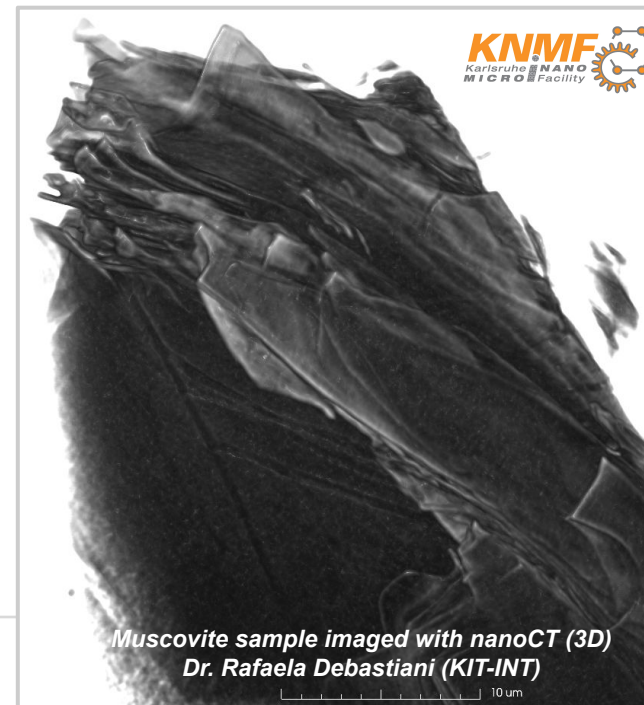
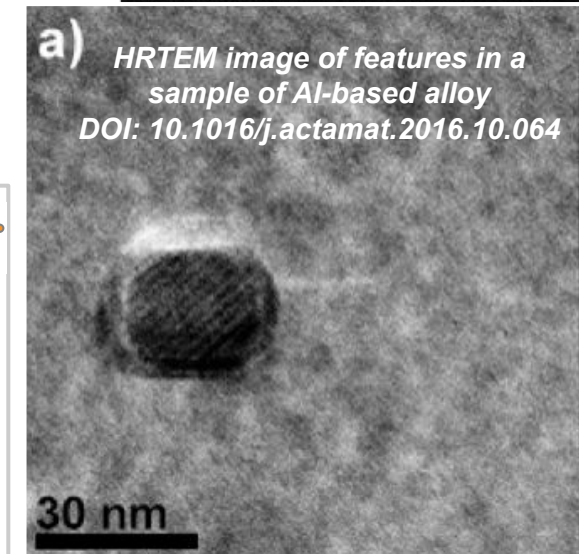
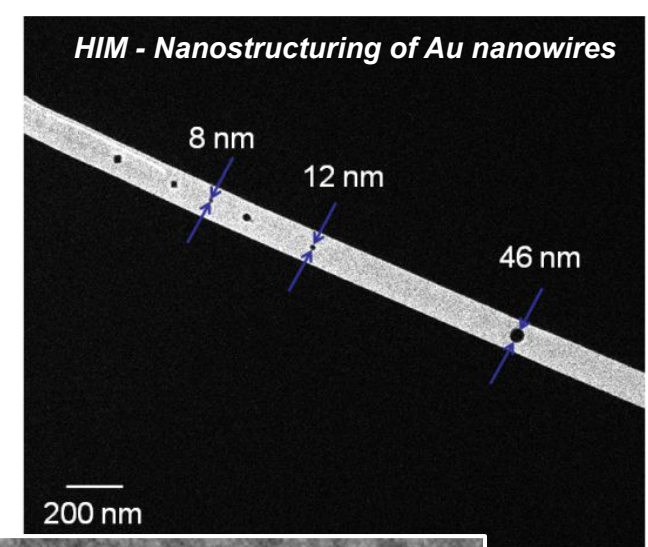
Institute of Nanotechnology (INT)



Unique nexus of expertise in Europe,
perfect for a mineral-detectors project!

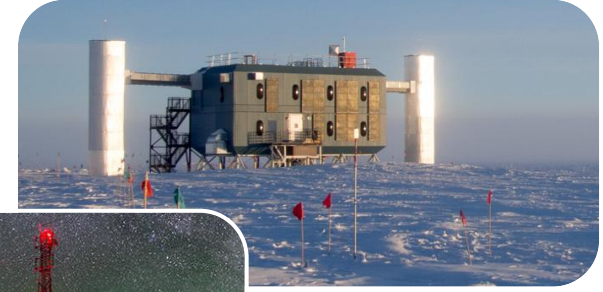
Combination of microscopy facilities

- ❖ Cutting edge nm-scale & μm -scale microscopy
- ❖ **Helium Ion Microscopy - HIM**
 - Resolution: $\leq 0.35 \text{ nm}$
 - FoV: $900 \mu\text{m}$ - 100 nm
- ❖ **Transmission Electron Microscopy (TEM)**
 - Resolution: $\ll 1 \text{ nm}$
- ❖ **nanoCT (3D)**
 - X-ray energy: 5.4 keV
 - FoV: $16 \mu\text{m}$ (HRES), $65 \mu\text{m}$ (LRES)
 - Resolution: $50 - 100 \text{ nm}$
 - Non-destructive



Many other microscopy facilities ...

Strong support for a long-term
mineral-detectors project



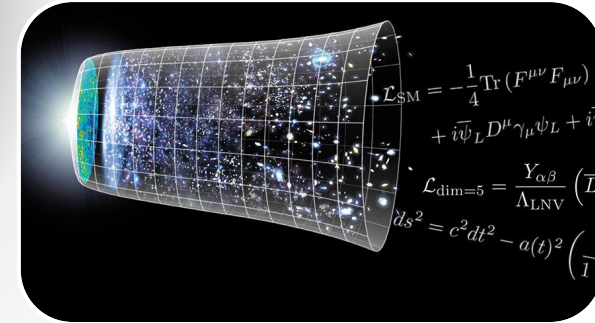
Pierre Auger Observatory - Cosmic rays



XENON/XLZD - Dark Matter & Neutrino detection



KATRIN - Neutrino precision mass measurement

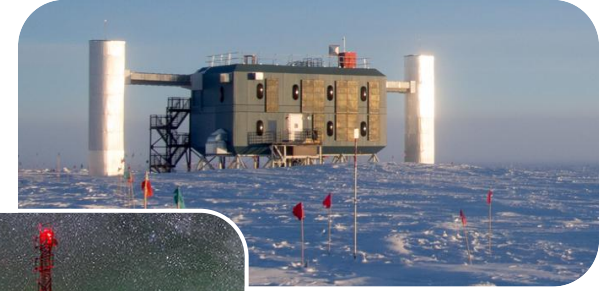


Theoretical particle & Astroparticle physics

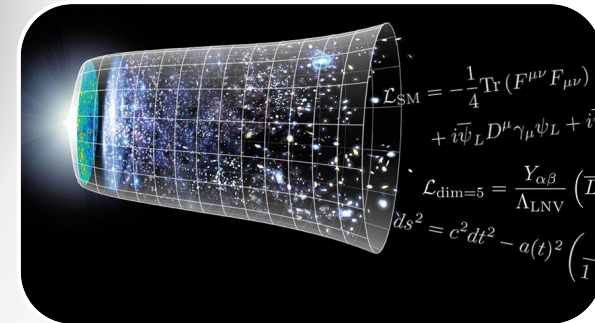
KIT-Zentrum Elementarteilchen und Astroteilchenphysik (KCETA)

Connecting experimental & theoretical research in astrophysics,
elementary particle physics & cosmology

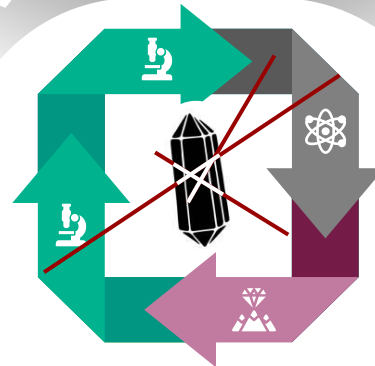
Strong support for a long-term
mineral-detectors project



Pierre Auger Observatory - Cosmic rays



Theoretical particle & Astroparticle physics



XENON/XLZD - Dark Matter & Neutrino detection



KATRIN - Neutrino precision mass measurement

Previously ...

2019 - 2020:

Heidelberg Karlsruhe Strategic Partnership (HEiKA)

- ❖ *“Searching for Dark Matter particle signatures with salt minerals as Palaeo-Detectors”*
- ❖ MSc & BSc theses
- ❖ Unique cooperation with geologists from Heidelberg University

K. Eitel & U. Glasmacher

HEiKA

2019

2020

2023

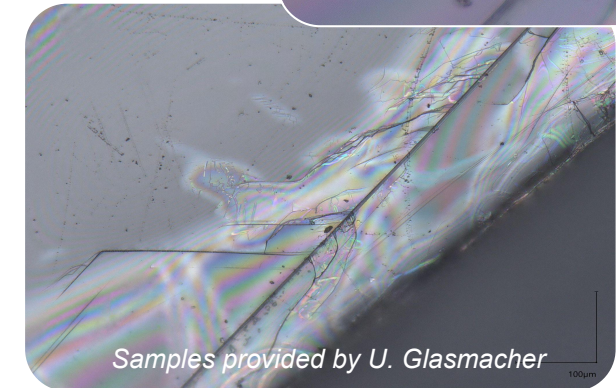
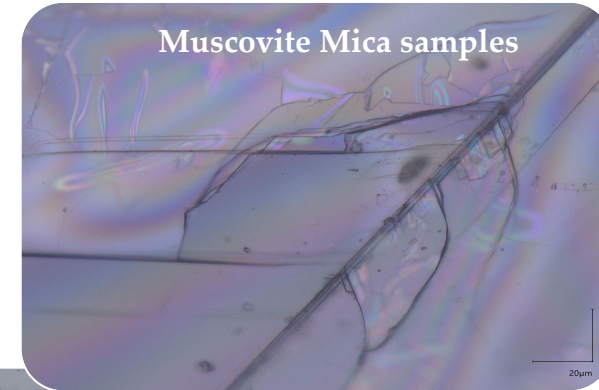
2024

2025

The Present ...

~2023 - Ongoing:

- ❖ Initial activities supported by KCETA
- ❖ MSc thesis project, HiWi project, another student from July
- ❖ **KNMFi** - official collaboration - access to nanoCT & other facilities



K. Eitel & U. Glasmacher

A. Elykov

HEiKA

2019

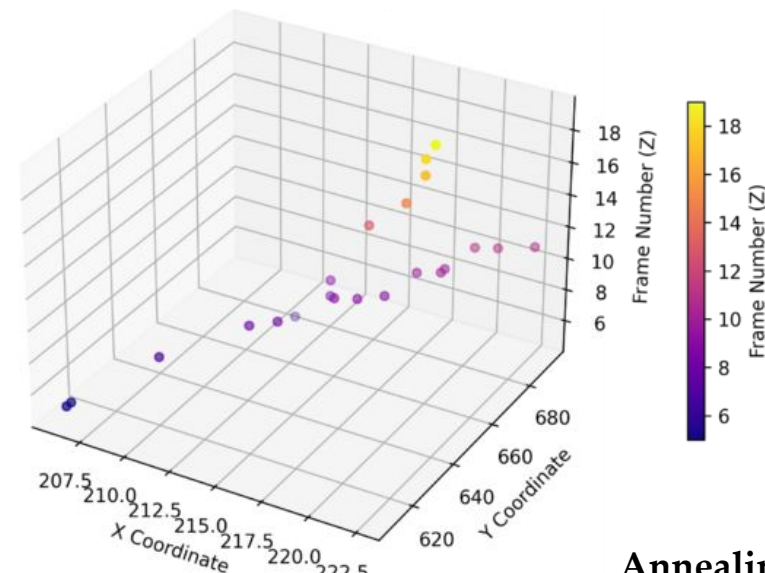
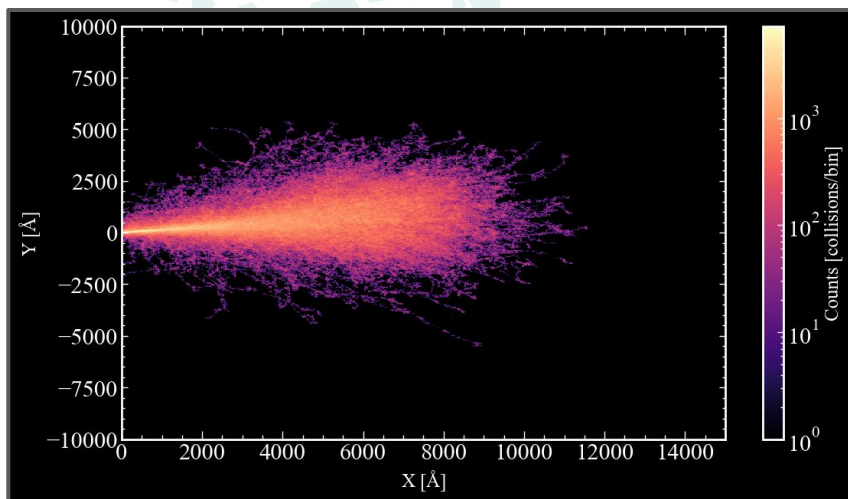
2020

2023

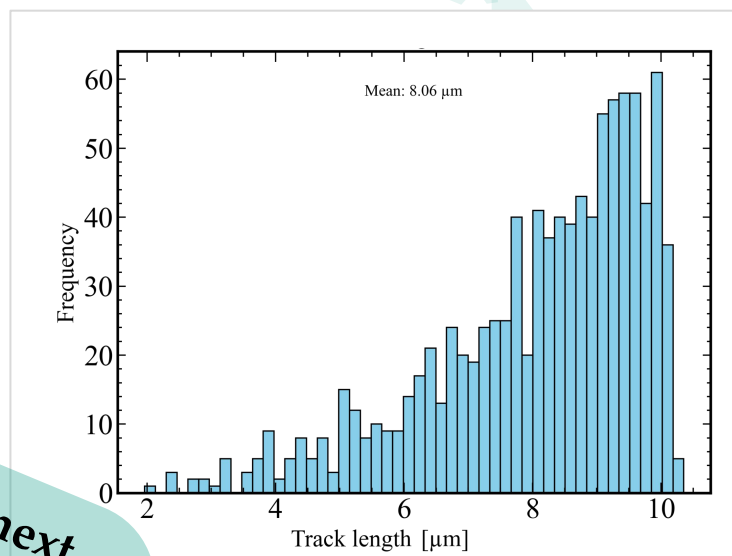
2024

2025

Ongoing Work - Student Projects



Track-length
simulation &
analysis

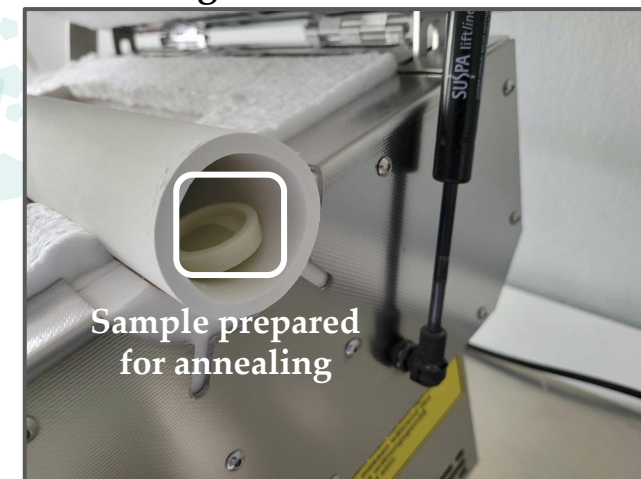


See next
talk!

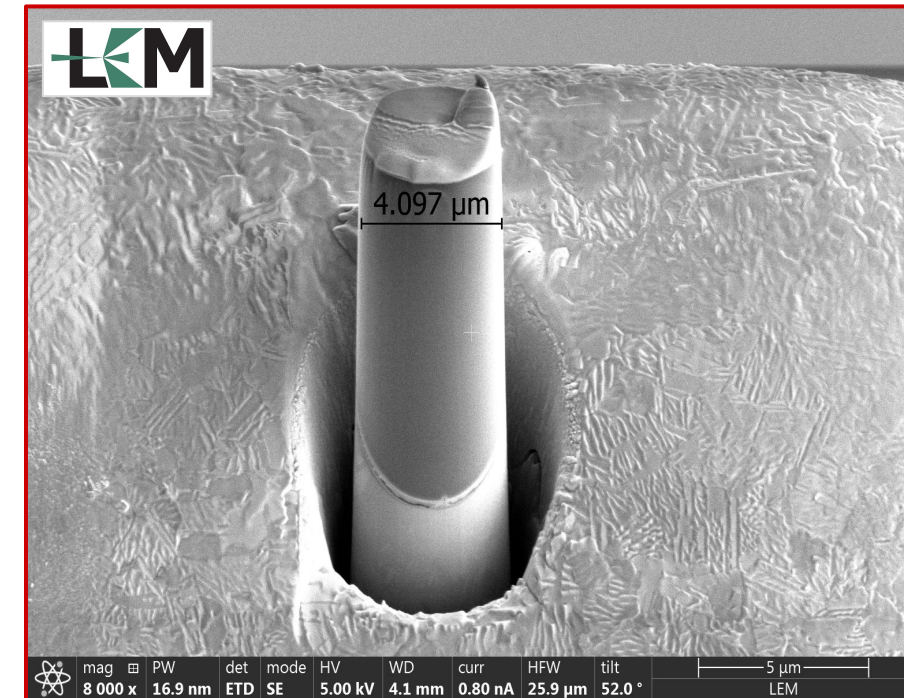
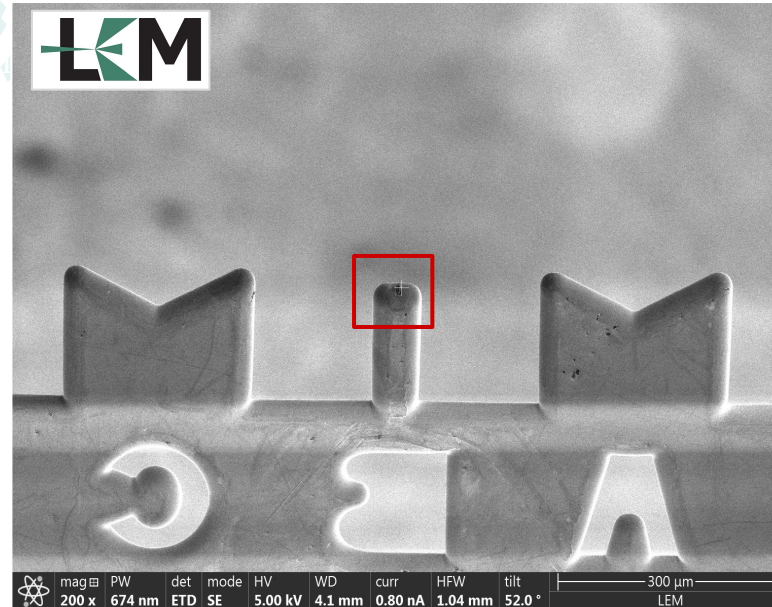


nanoCT image
analysis with ML

Annealing studies in a tube furnace

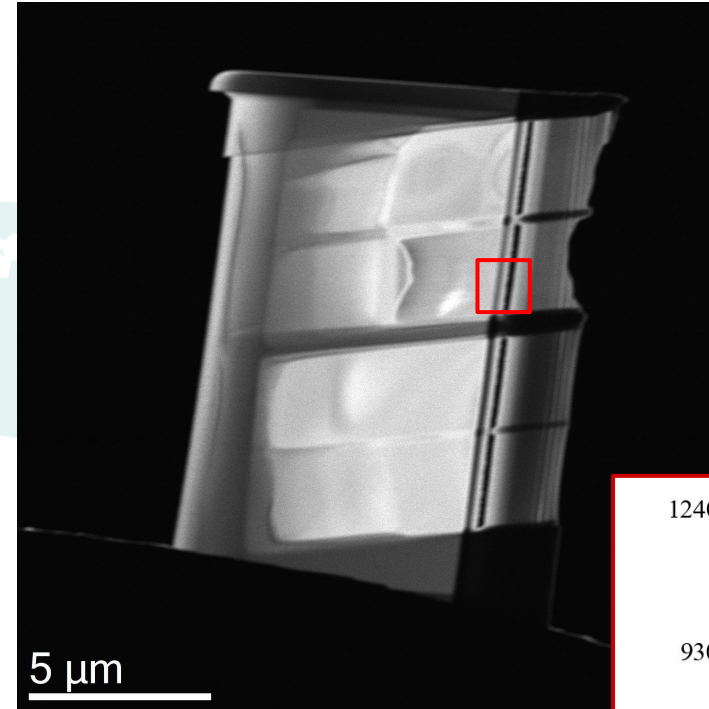
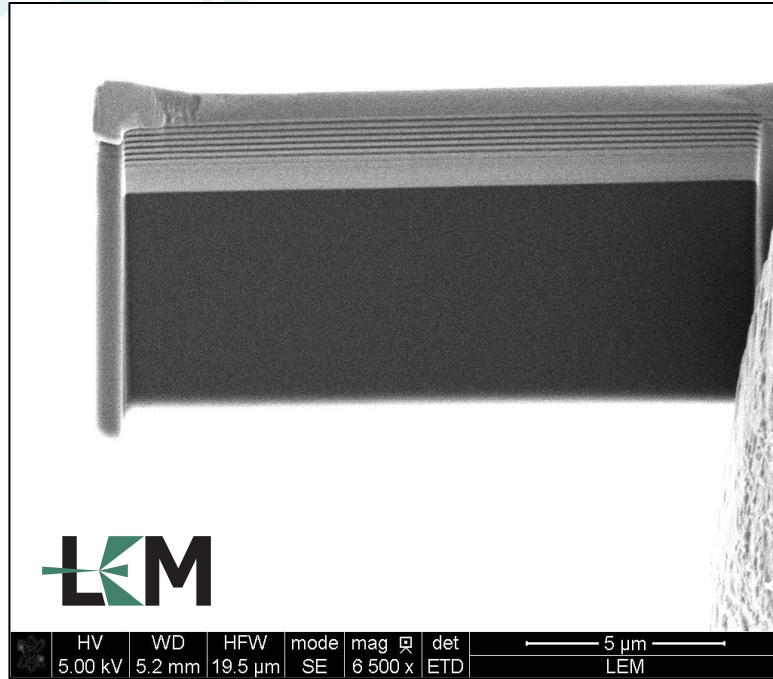


Ongoing work - Sub-sample preparation

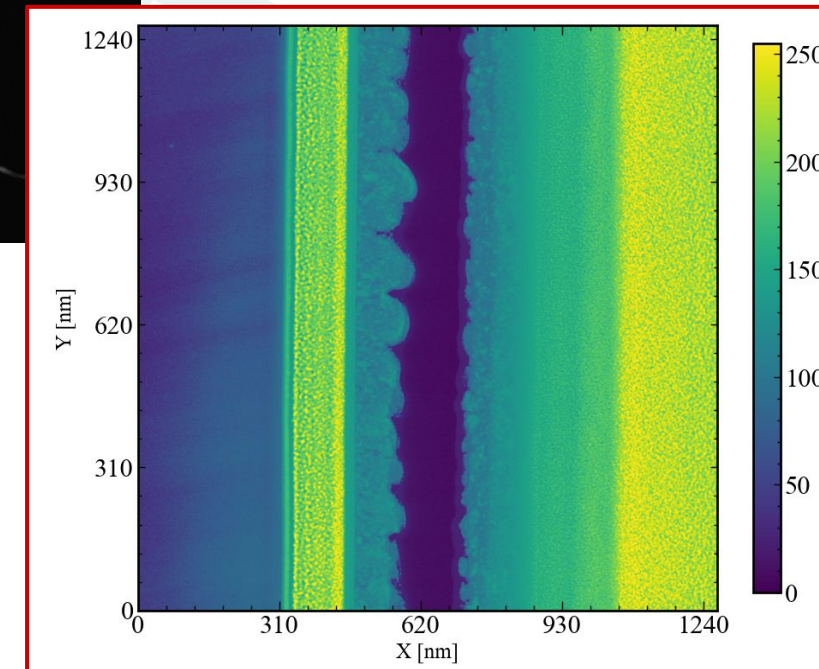


- ❖ Multiple mineral samples - irradiated & “blank”
 - ❖ **Biotite** - MeV Xe Ions, courtesy of U. Glasmacher (U. Heidelberg)
 - ❖ **Si & Muscovite** - keV/MeV As ions, DT MeV neutrons
- ❖ Exploring techniques for sub-sample preparation & imaging

Ongoing work - TEM



Si Lamella imaged with TEM

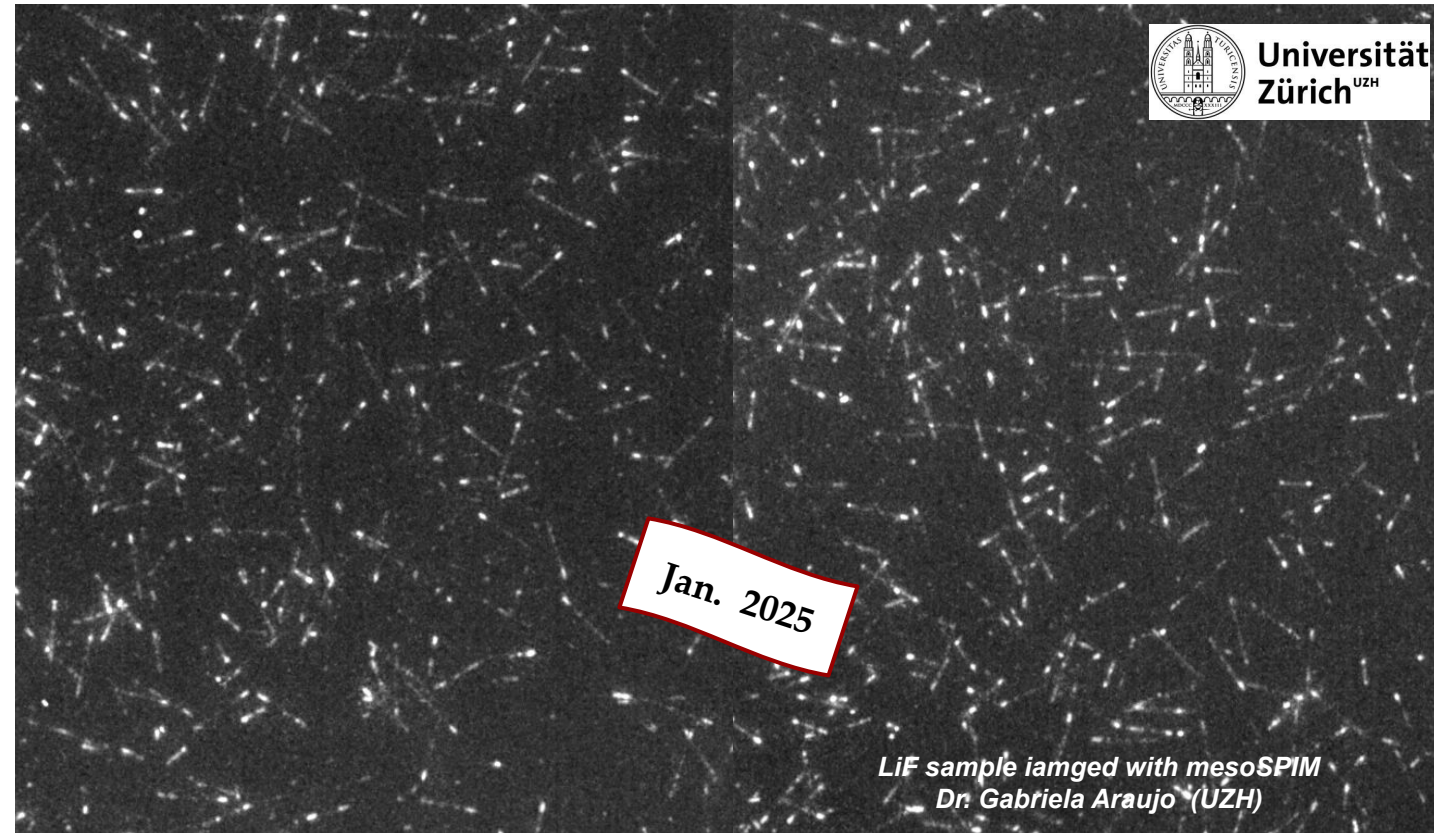


- ❖ Multiple mineral samples - irradiated & “blank”
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- ❖ Exploring techniques for sub-sample preparation & imaging

Ongoing work - LiF (color centers)

Simulations, irradiation & microscopy studies:

- ❖ DT MeV neutrons (Frascati)
- ❖ Alphas, ions & imaging (U. Zurich, ETH)



Ongoing work - LiF (color centers)

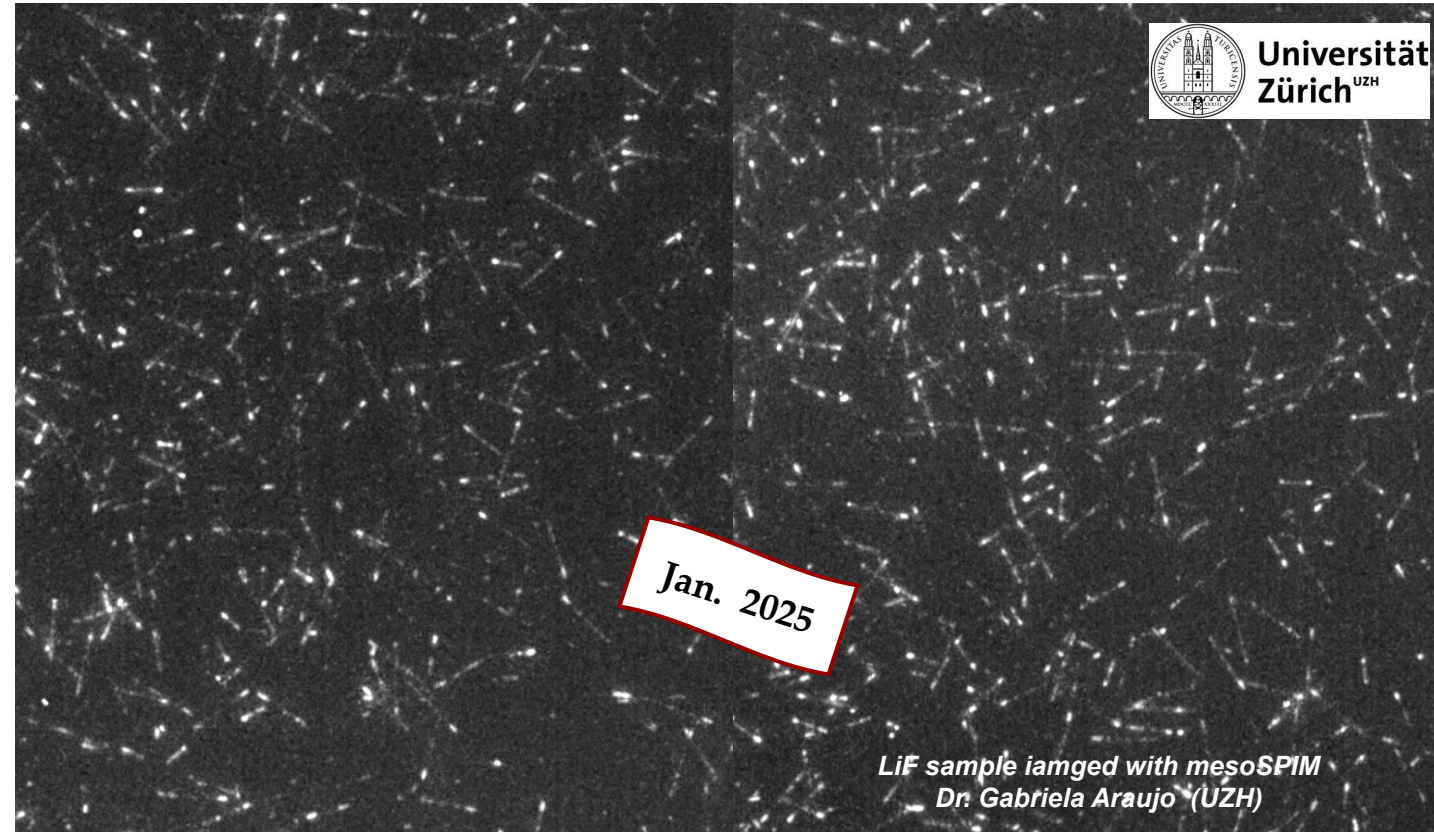
Simulations, irradiation & microscopy studies:

- ❖ DT MeV neutrons (Frascati)
- ❖ Alphas, ions & imaging (U. Zurich, ETH)



... unfortunately the sample was lost ...

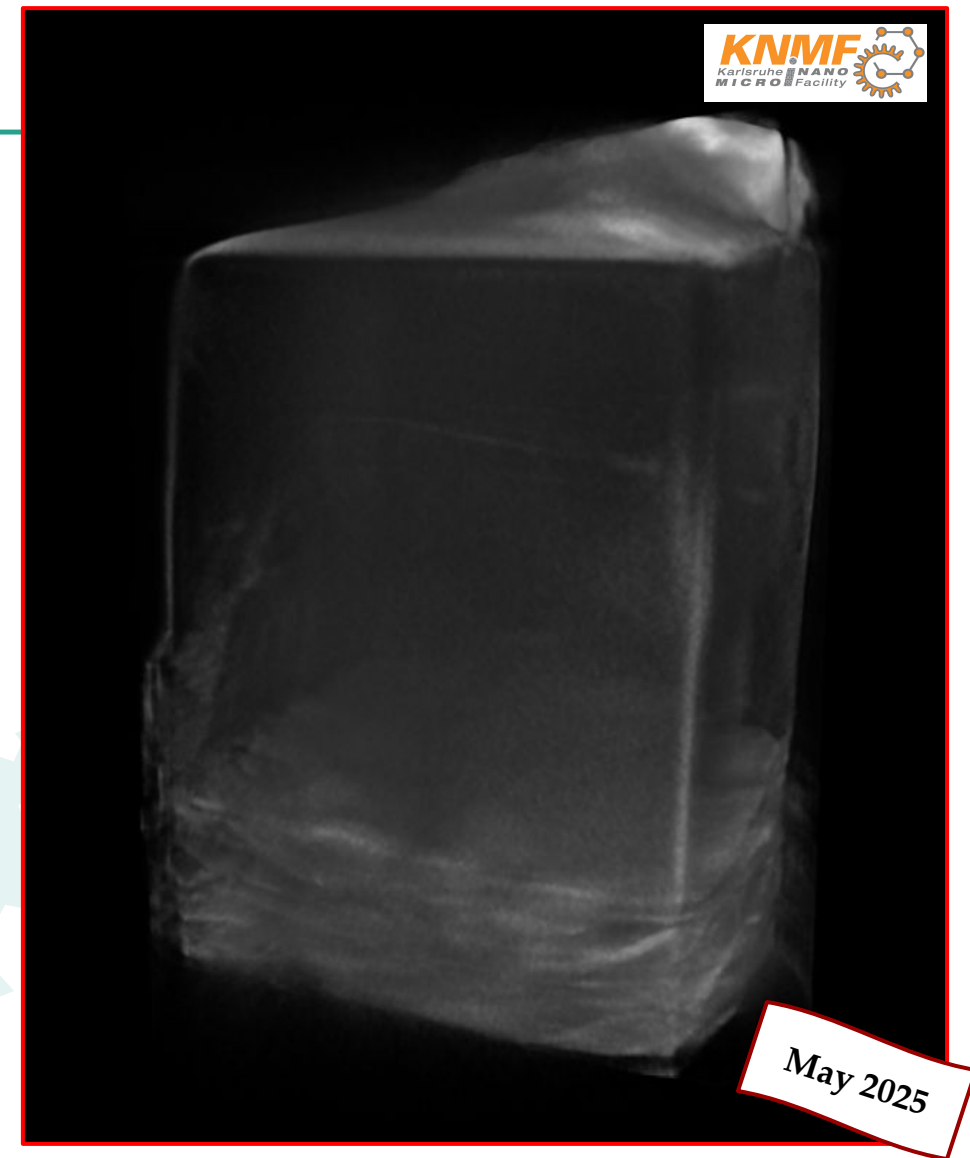
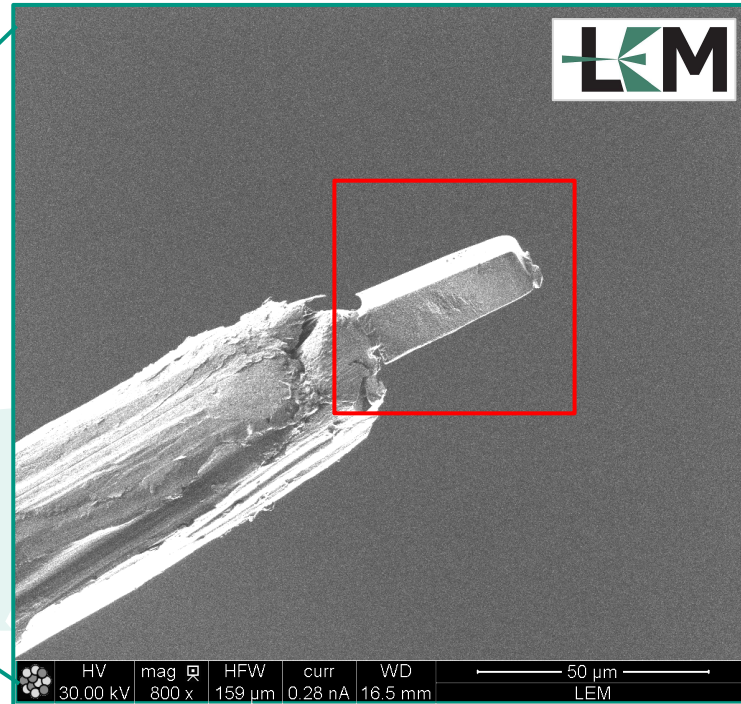
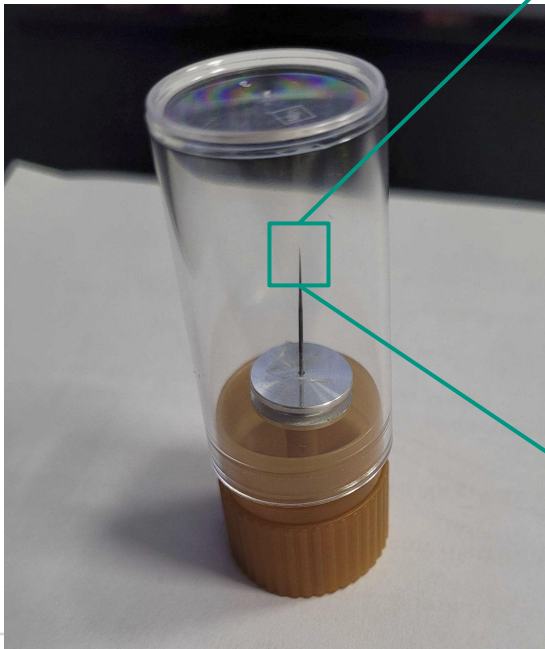
We can irradiate another one
& try again.
You're welcomed to join us!



Ongoing work - Si (nanoCT)

❖ Si pillar sub-sample (1 MeV As ions)

- Sub-sample preparation & imaging
- Simulations to guide imaging



Summary & Outlook



- ❖ **KIT - Unique combination of different facilities & expertise**
 - Perfect place for a mineral detector project

- ❖ **Preliminary studies ongoing - can we image low-energy nuclear recoils?**
 - Software development for simulations, image analysis
 - Calibration & imaging studies with microscopy experts

Trying to establish a long-term mineral detector project. Contact us!



MDvDM 2026

Karlsruhe, Germany