

ER-C 2.0

**RAFAL E. DUNIN-BORKOWSKI,
JOACHIM MAYER,
AND CARSTEN SACHSE**

**National user facility for high-
resolution electron microscopy**

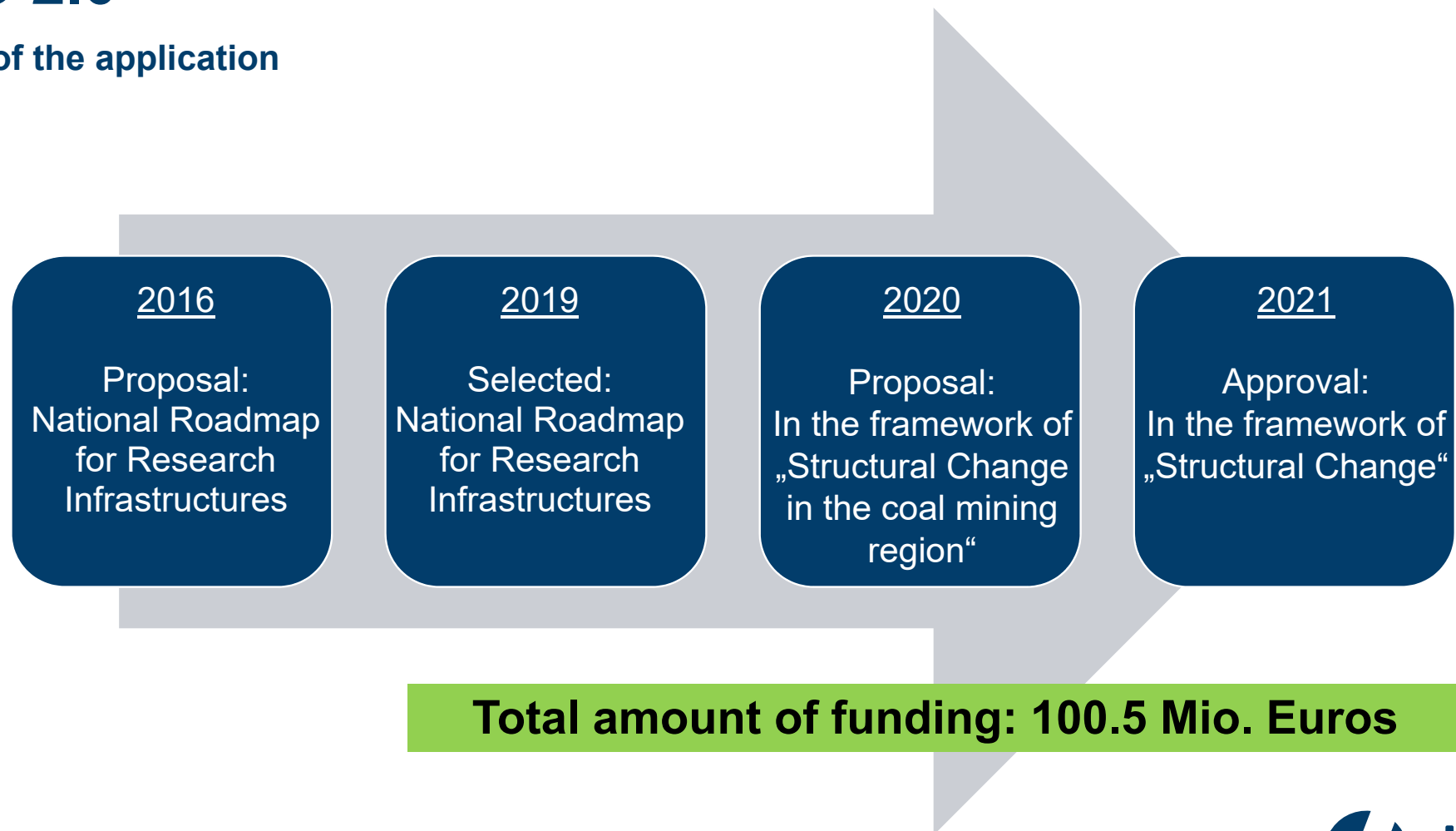
Mitglied der Helmholtz-Gemeinschaft

Call launched in summer of 2015



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History of the application



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Laboratory and office building

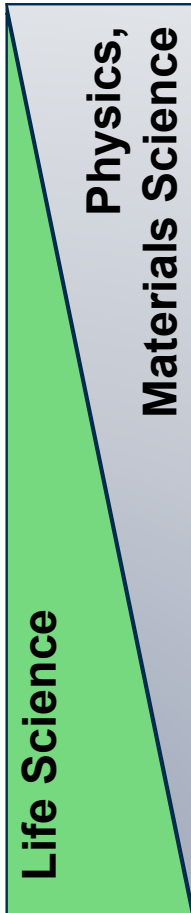


Mitglied der Helmholtz-Gemeinschaft

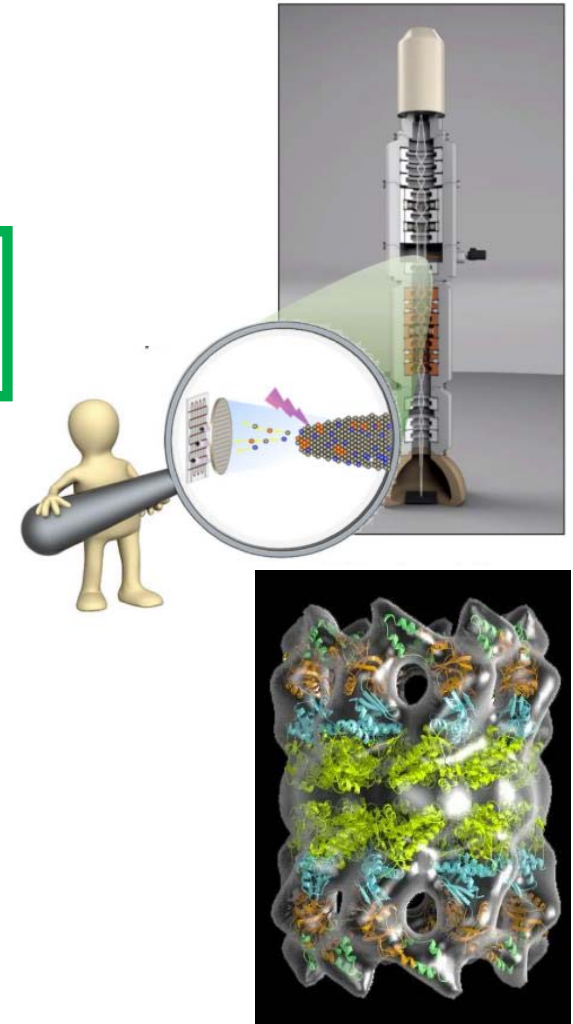


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Five Internationally unique Instruments



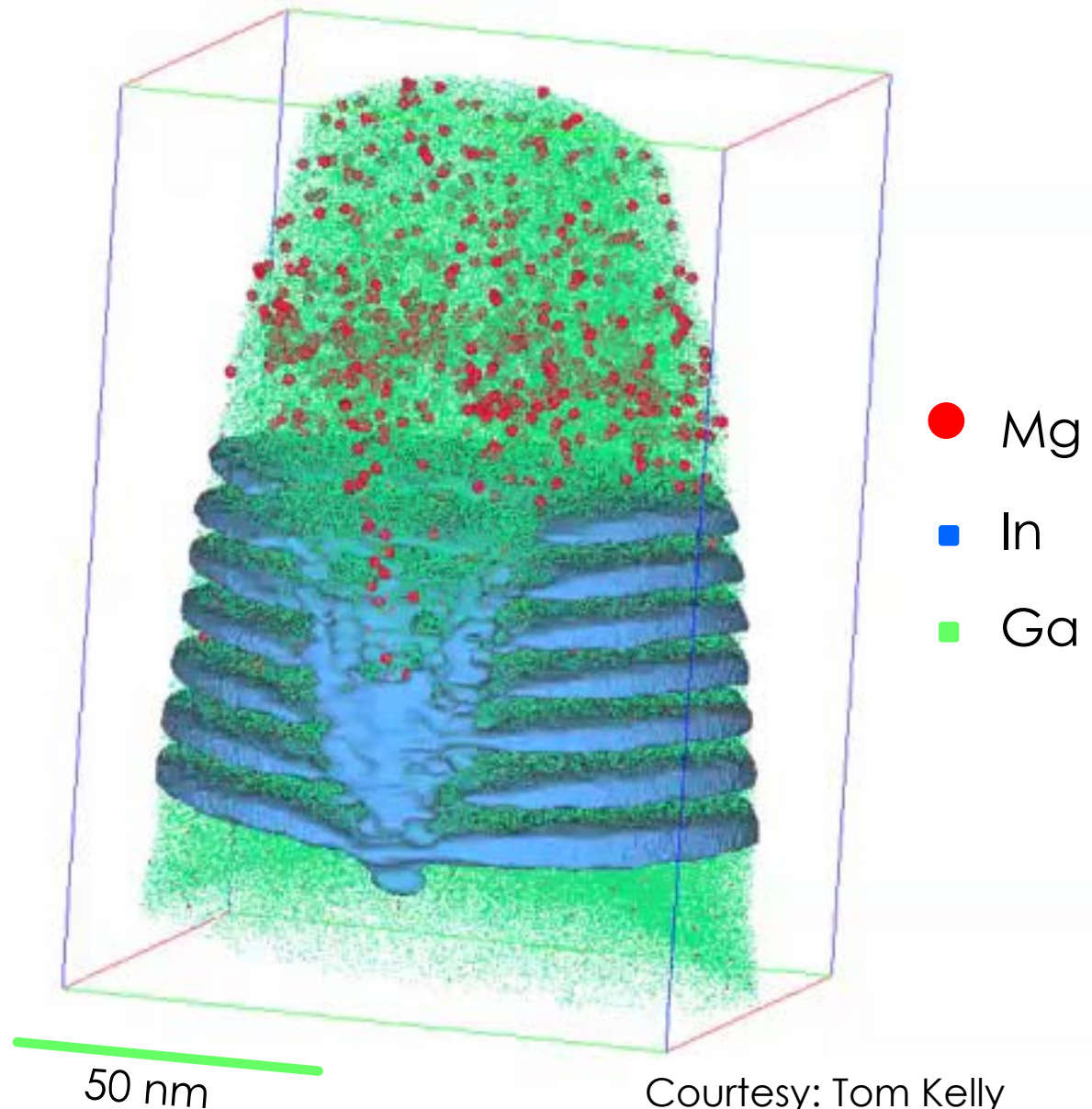
- **TOMO:**
TEM combined with an integrated atom probe
- **OPERANDO:**
Liquid-He cooled UHV-(S)TEM for *in situ* experiments
- **FEMTO:**
Dynamic *in situ* TEM with ps time resolution
- **SPECTRO**
Low Voltage (S)TEM with highest spectroscopic resolution
- **BIO:**
Biological TEM with Cc corrector, phase plate, energy filter, He cooling and single electron detector

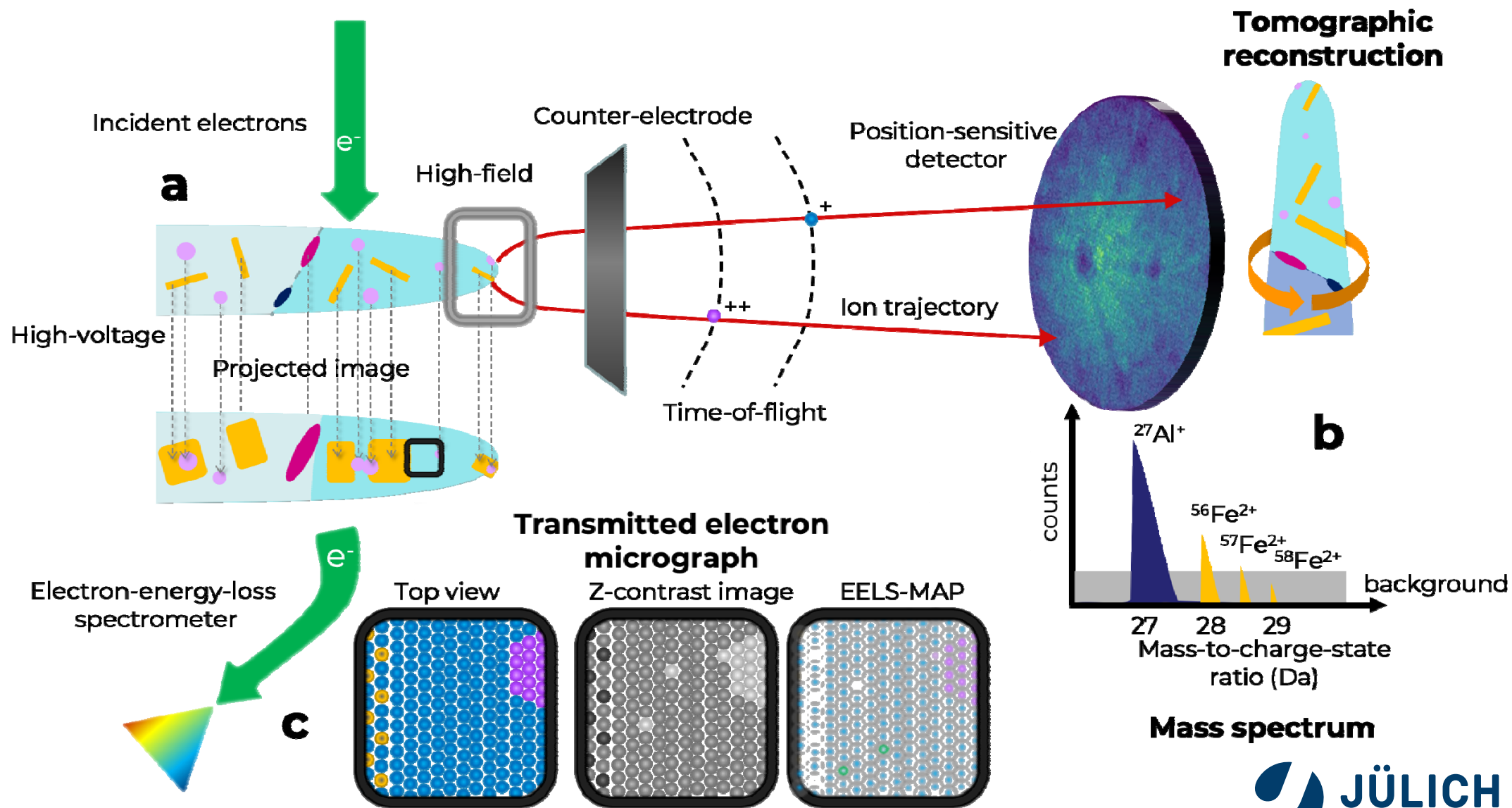


Atom Probe Tomography

GaN LED for Lighting

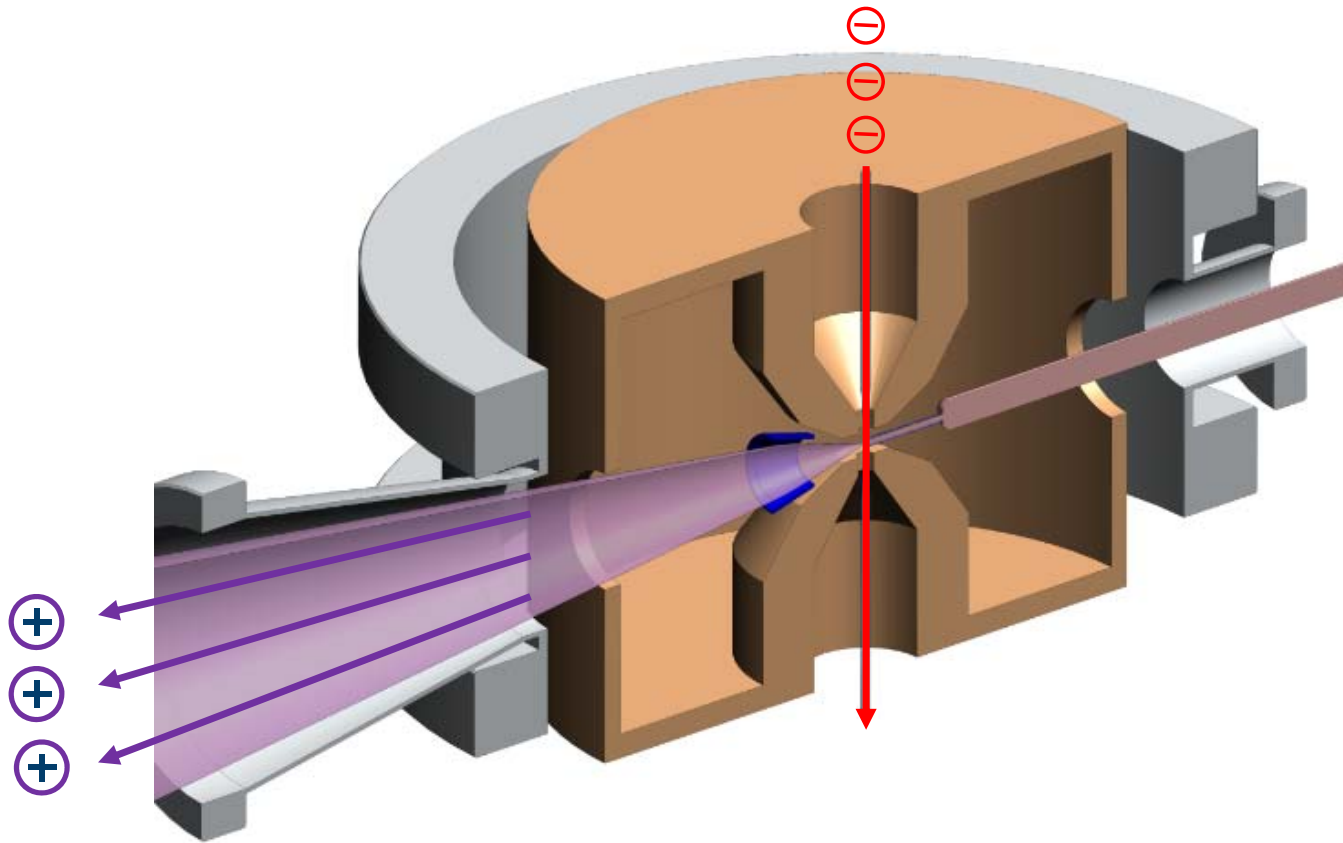
- 3D image 😊
- 30 million atoms 😊
- 80% of the atoms 😊
- Spatial Resolution, δr
 - 0.1 nm < δr < 3 nm 😊 😞



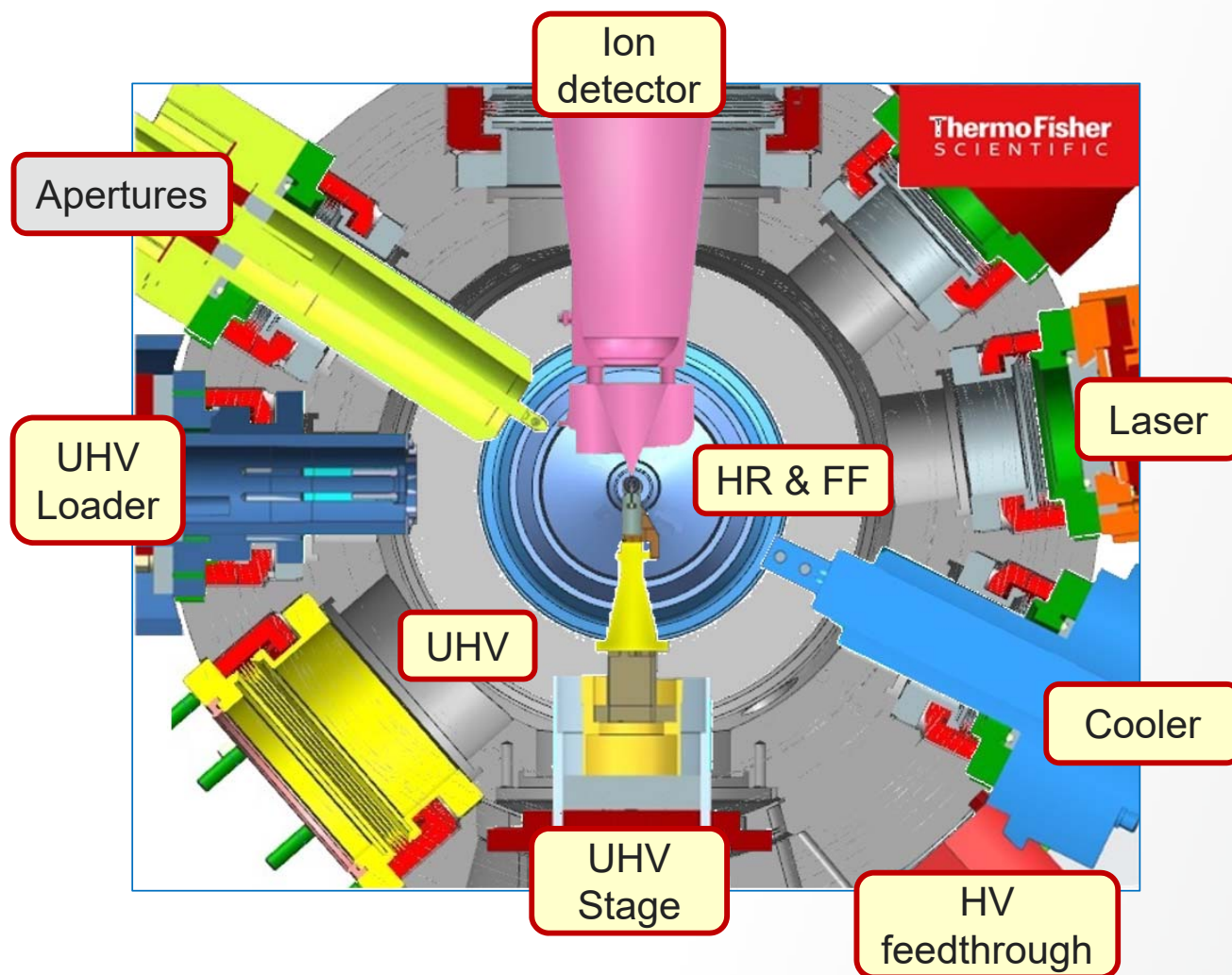


TOMO:

Basic Instrument Design



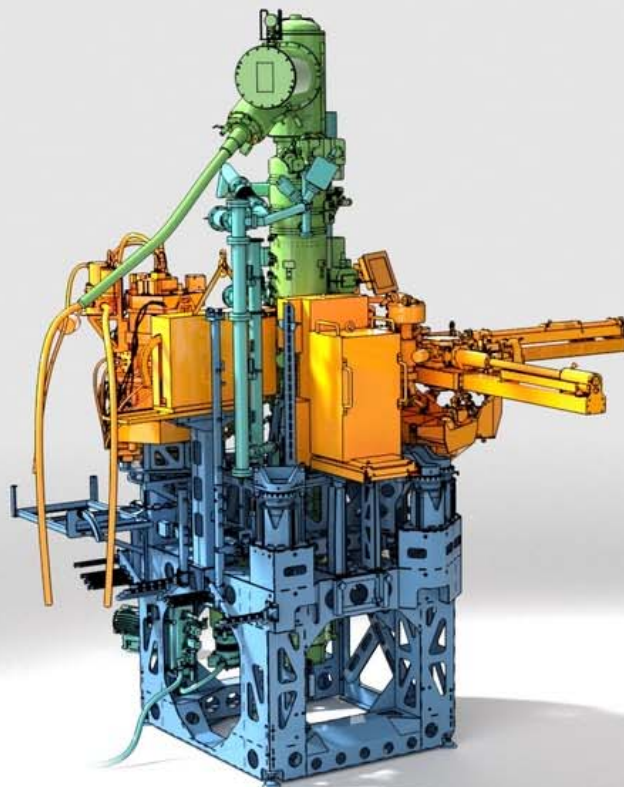
Principal instrument functions/components



- Laser
- Ion Detector
- Specimen chamber
 - Ultra High Vacuum
 - Optics
- Stage
- Loader
- Cooler
- ... and many more:
 - Elongated correctors
 - Holography
 - Tomography
 - 4x electrical contacts
 - Scripting access
- Coincidence

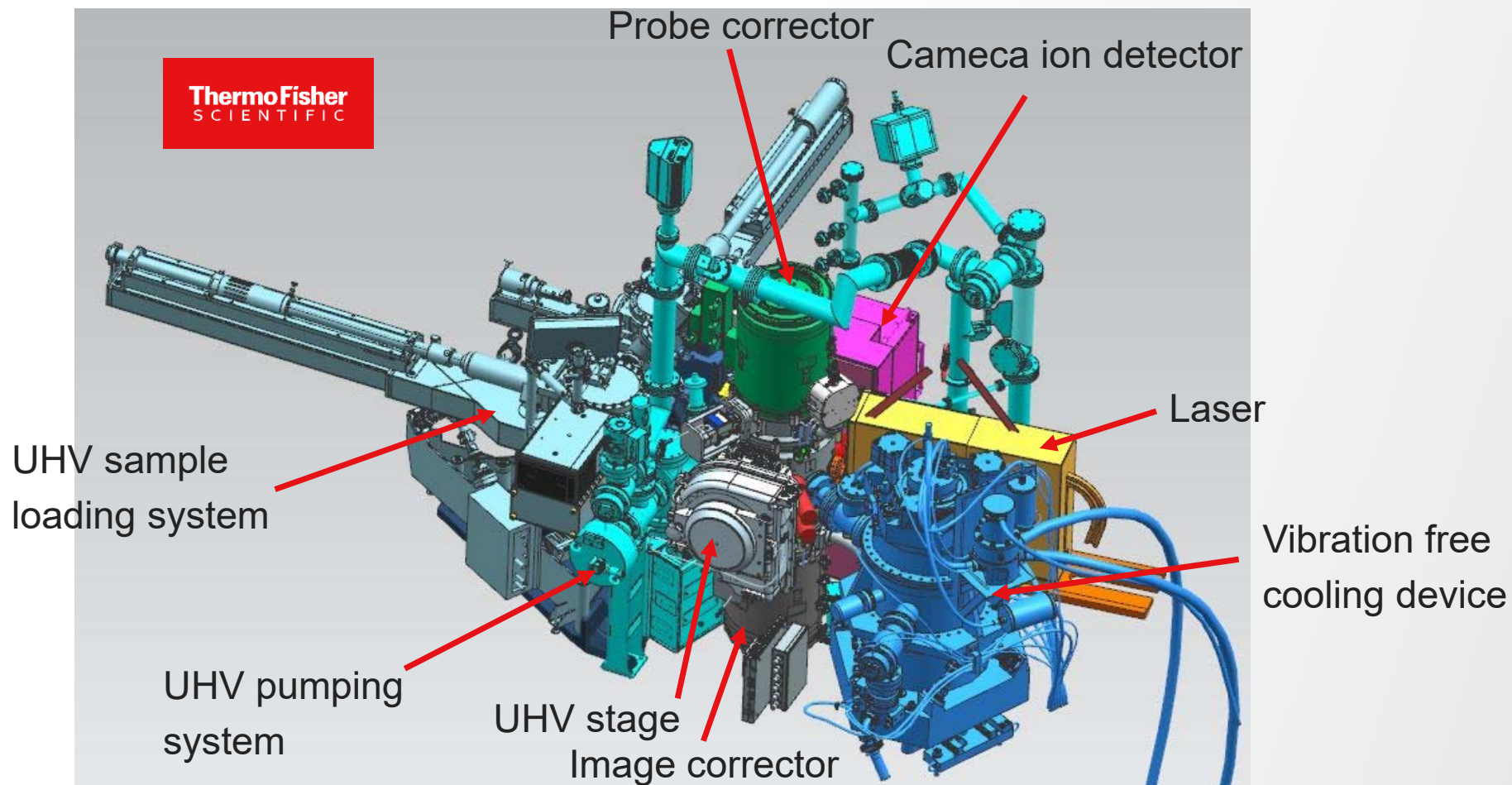
ER-C 2.0: TOMO instrument - overview

ThermoFisher
SCIENTIFIC



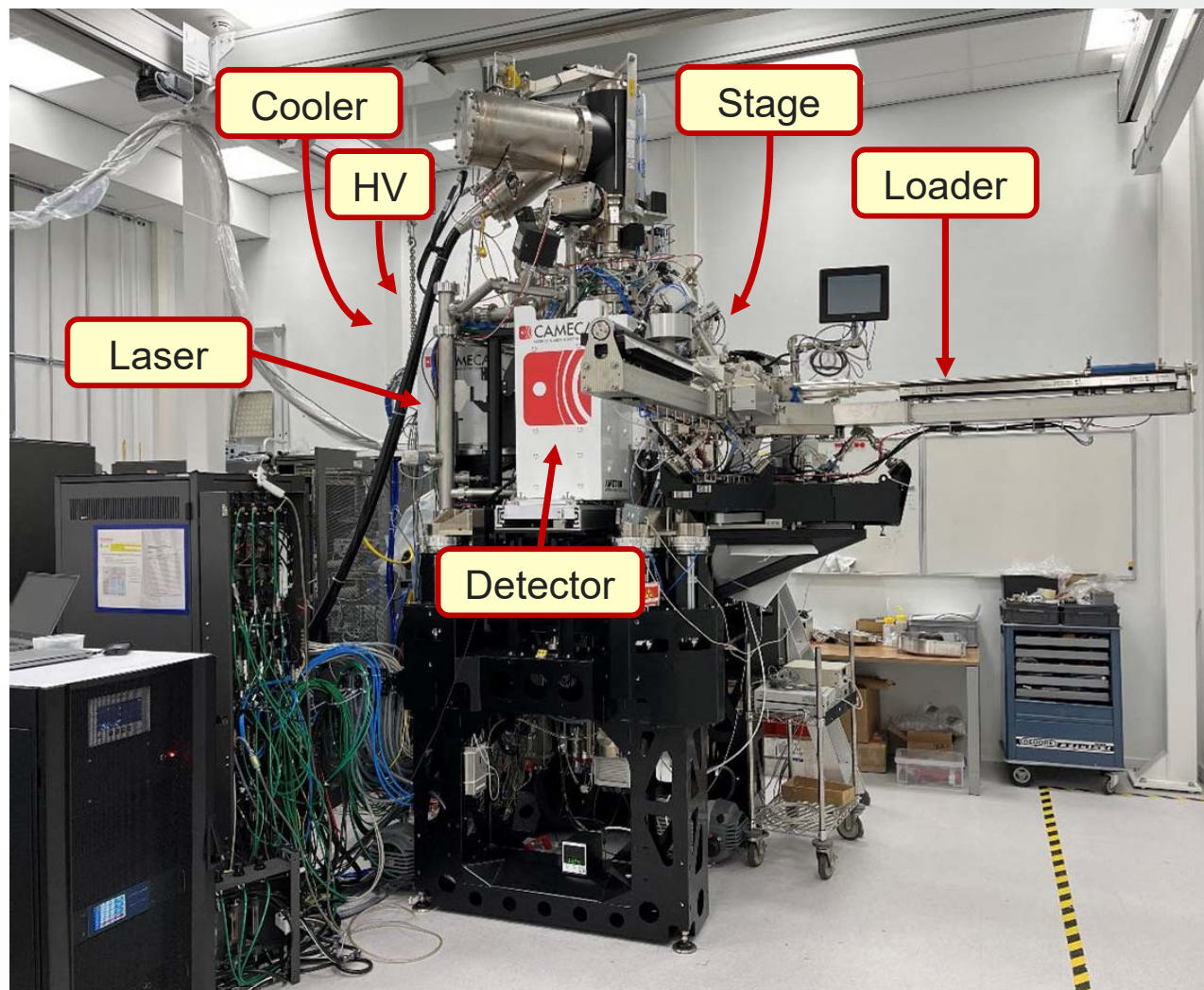
ThermoFisher
SCIENTIFIC

TOMO column with components around octagon



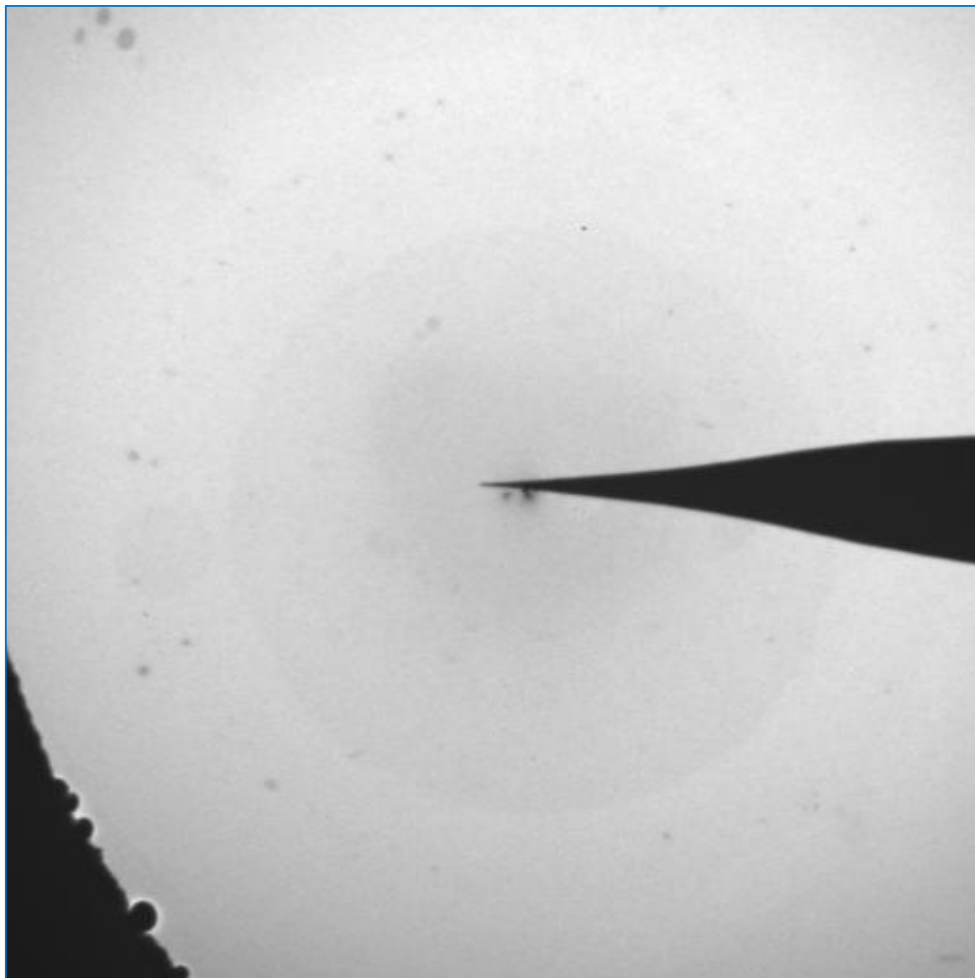
Jülich TOMO prototype

- Integrated APT on TEM
- Uncorrected 300 kV instrument
- Principal system component test
- Experimentation workflow test

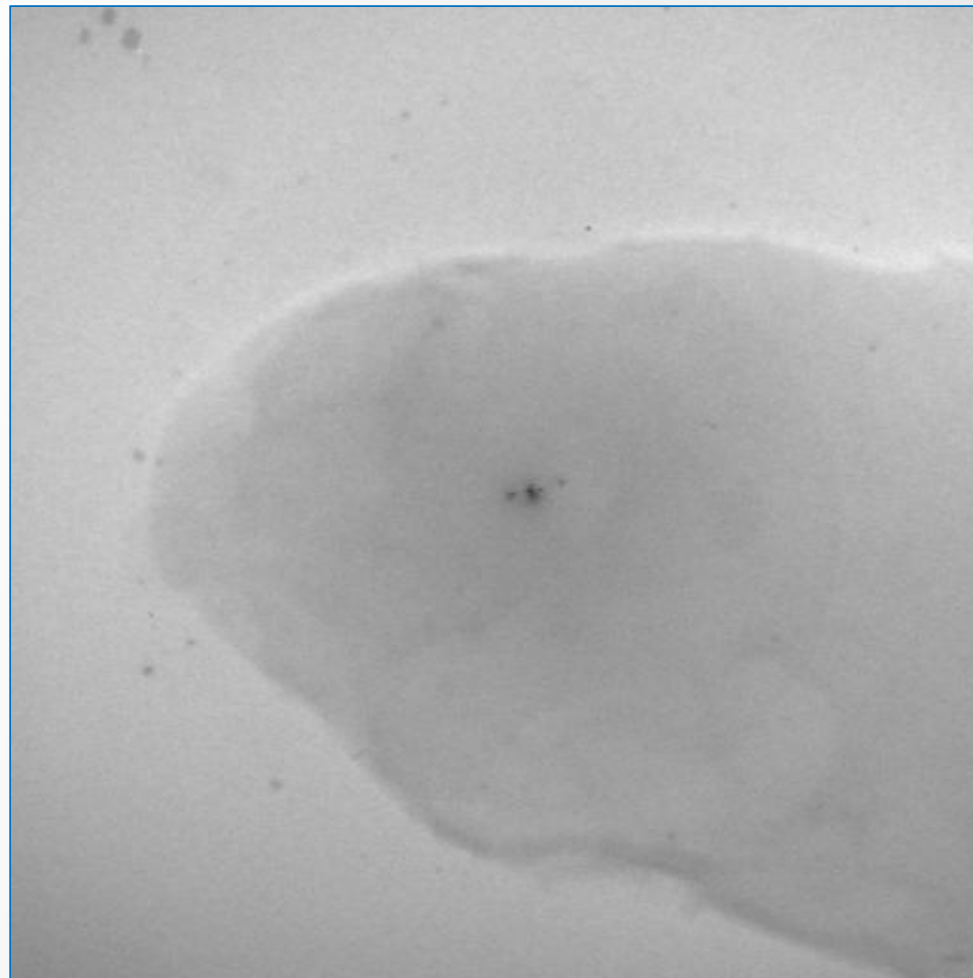


First APT data on TOMO TEM – Aluminium Reference

Field free mode 630 x



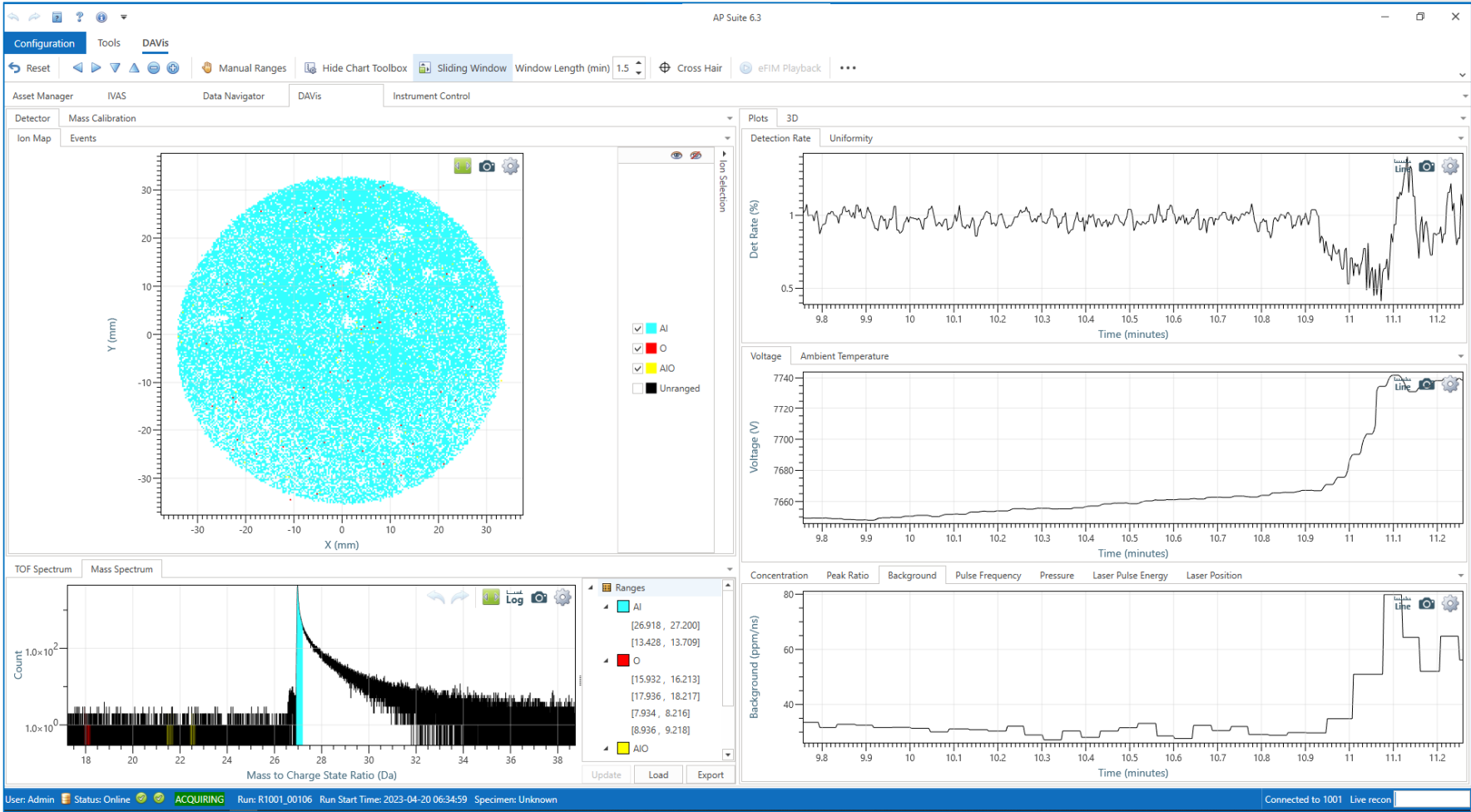
SA 57 kx



Intermittently evaporate the needle ...

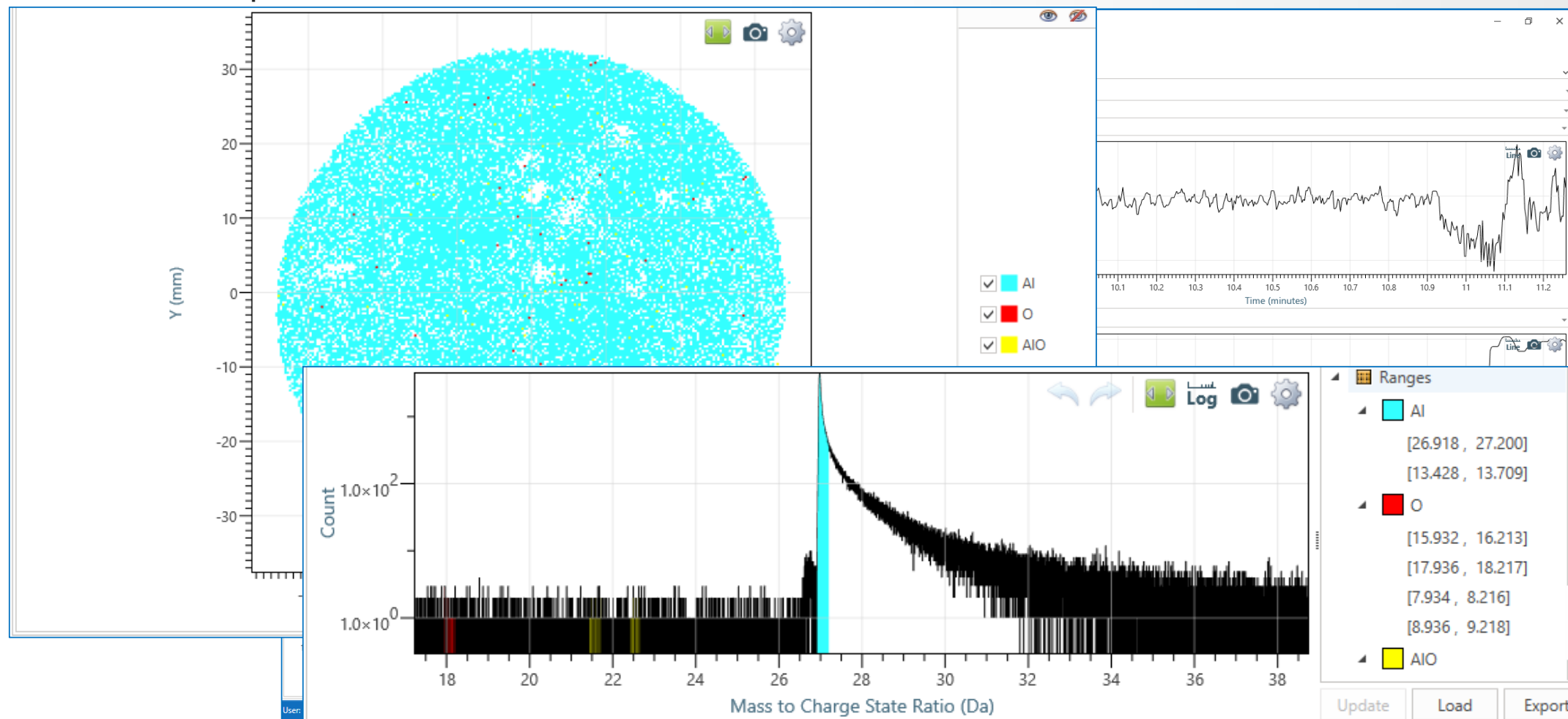


CAMECA atom probe suite



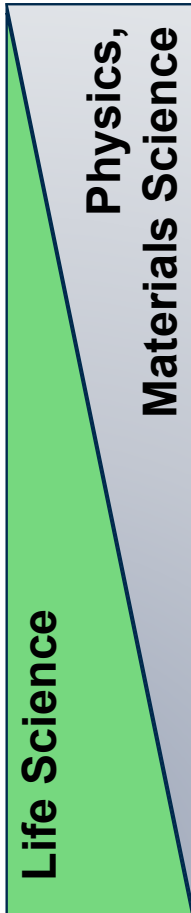
Intermittently evaporate the needle ...

CAMECA atom probe suite

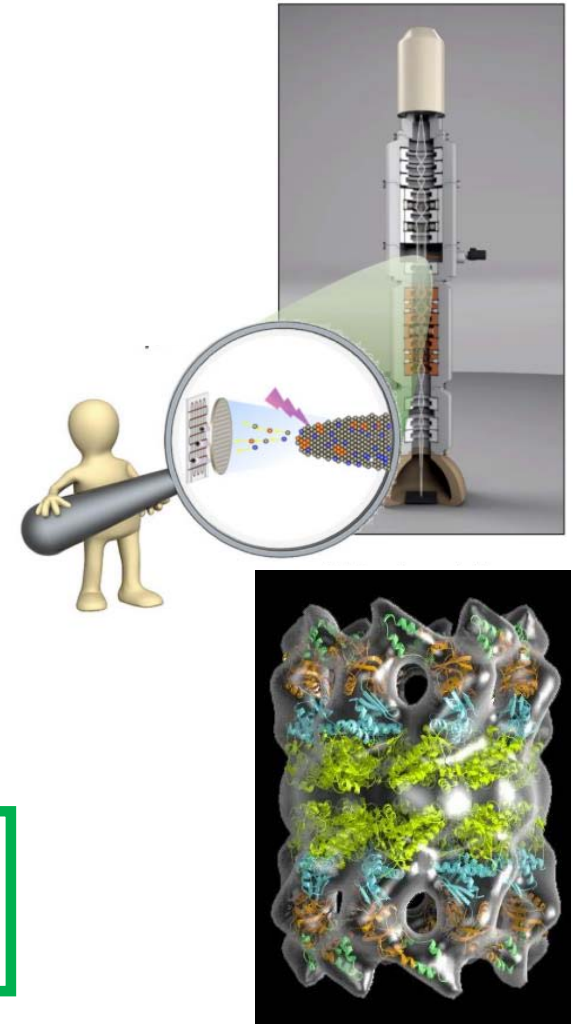


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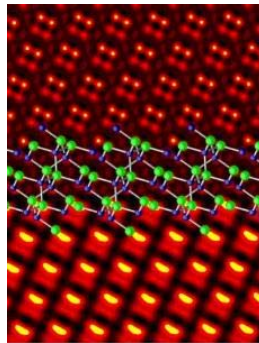


Electron cryo-microscopy at the Ernst-Ruska Centre (ER-C)

ER-C

Foundation of
Ernst-Ruska Centre
(Material science
microscopy)

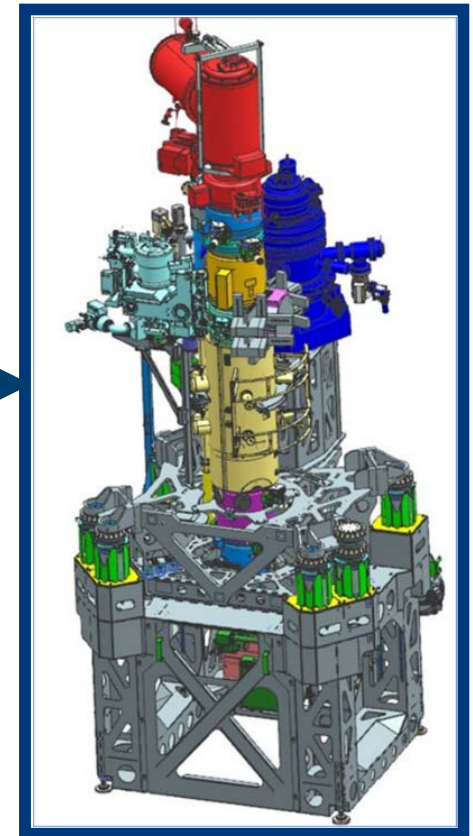
0.5 Å resolution



TFS Titan Krios
TFS Aquilos 2



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2004



2011

Titan Pico
microscope with
0.5 Å resolution

2019



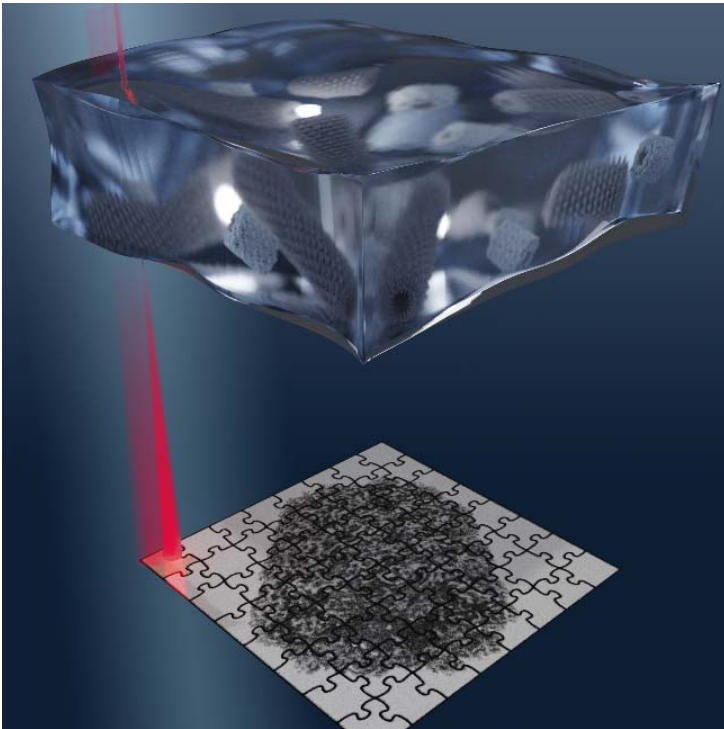
TFS Talos 120C
TFS Talos Arctica

2022

2024

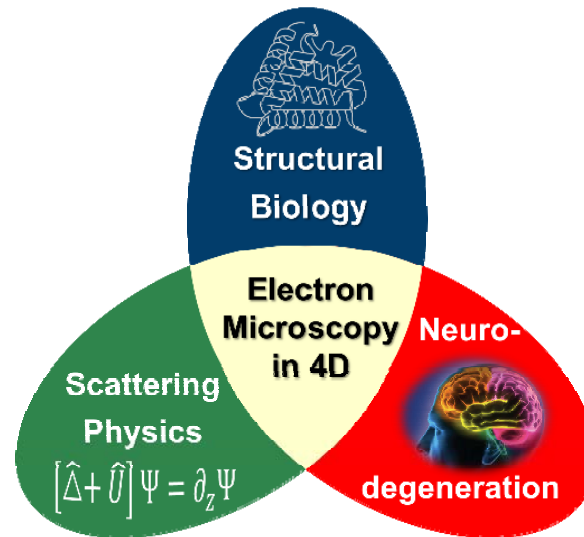
BIO instrument
Helium/Cc-
correction

Cryo-STEM imaging of biological specimens



Lazic et al., *Nature Methods* 2022
Lazic and Sachse, *Nature Briefing* 2022

Mitglied der Helmholtz-Gemeinschaft



European Research Council

Established by the European Commission

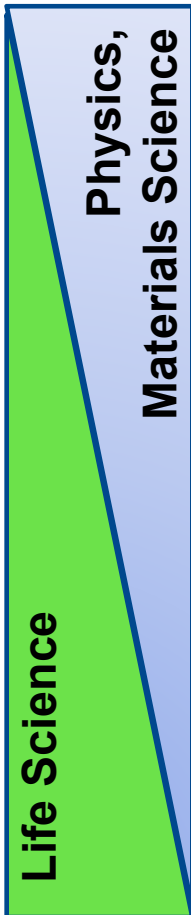
ERC Synergy Grant: 4D BioSTEM

Carsten Sachse
Henning Stahlberg
EPFL

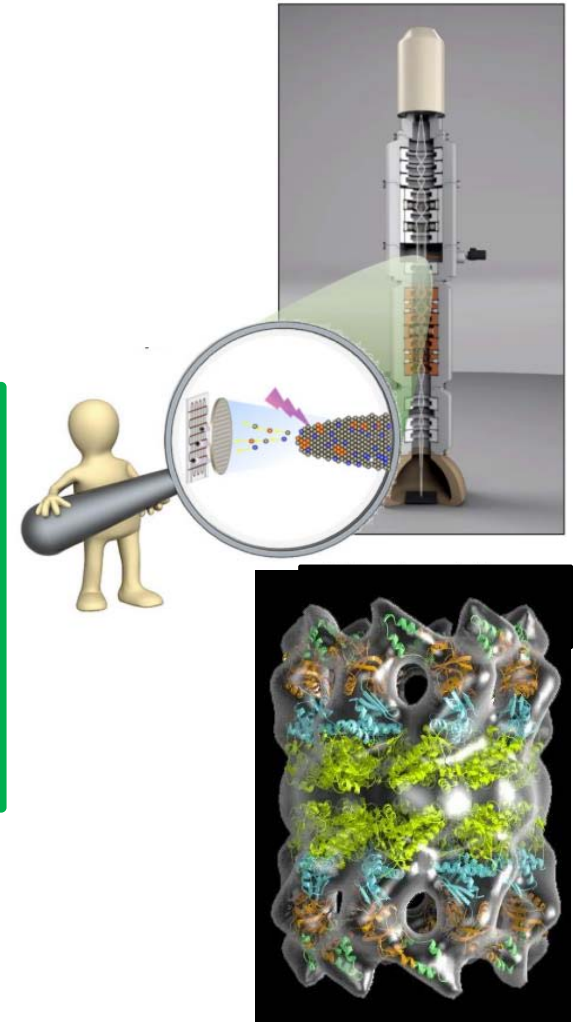
Knut Müller-Caspary
LMU Munich

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ER-C 2.0 instruments

OPERANDO (to arrive in 2025):

- **Deep UHV** (fully bakeable) image Cs corrected (S)TEM with *in situ* deposition using thermal laser epitaxy
- Features: **liquid-helium-cooled cartridge-based specimen stage**, *in situ* gas dosing, UHV specimen transfer, magnetic-field-free imaging, electron biprisms

OPERANDO (connected tools):

- **Deep UHV FIB** with four columns (plasma FIB, Cs FIB, SEM, SIMS), cryo transfer, EDS / EBSD and future direct connectivity to other UHV instruments
high resolution SIMS using improved ion optics
- **Surface science cluster** for preparing atomically clean surfaces by H etching, O etching, heating and metal deposition, with connectivity to UHV surface science techniques (AFM, spin polarized STM, AES) and to ***ex situ* deposition in an exact copy of the UHV (S)TEM column.**

FEMTO:

- Laser-driven Cs corrected field emission TEMs for **ultrafast and dynamic studies** in pulsed and continuous modes and unique gun and lens designs.
- **UTEM: Double Cs corrected ultrafast (S)TEM** for studies of ps to fs reversible phenomena, **1-2 Å magnetic-field-free resolution in STEM and TEM modes**, **cryo workflow** and additional space for phase plates.
- **DTEM: Image Cs corrected dynamic (S)TEM** for irreversible studies with μ s to ns temporal resolution, **cryo workflow**, **extra wide pole piece gap**.
- **To arrive in 2025.**

SPECTRO:

- **Ultra-high-energy-resolution** monochromated probe Cs corrected STEM with **light injection and collection**, a **liquid-helium-cooled specimen stage**, **magnetic-field-free imaging with 2 Å spatial resolution**, gas injection, beam blanking, compatibility with cartridge-based sample transfer and additional ports.
- Correlative environmental SEM with gas injection (N₂, O₂, Ar, CH₄, CO, H₂), residual gas analyzer, heating stage, **co-located Raman and CL spectrometers**, 4D STEM with variable camera length, EDX and EBSD for multiscale, integrated and *in situ* correlative characterisation.
- **To arrive in 2025.**