HZB Helmholtz Zentrum Berlin

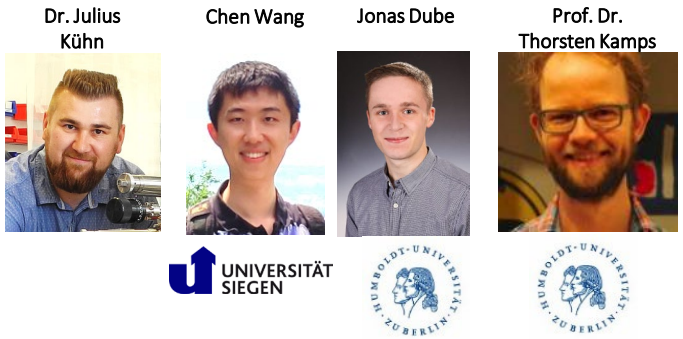
# Na-K-Sb Photocathodes at HZB: Growth, Characterization & Operation

**Dr. Julius Kühn**

Department High Brightness Beams

# Accelerator Division
# Department high brightness beams

## Photocathode R&D




## Drive Laser and Laser Beam Transport

## Beam dynamics and instrumentation

## Beam Applications

# Helmholtz-Zentrum Berlin, Adlershof campus

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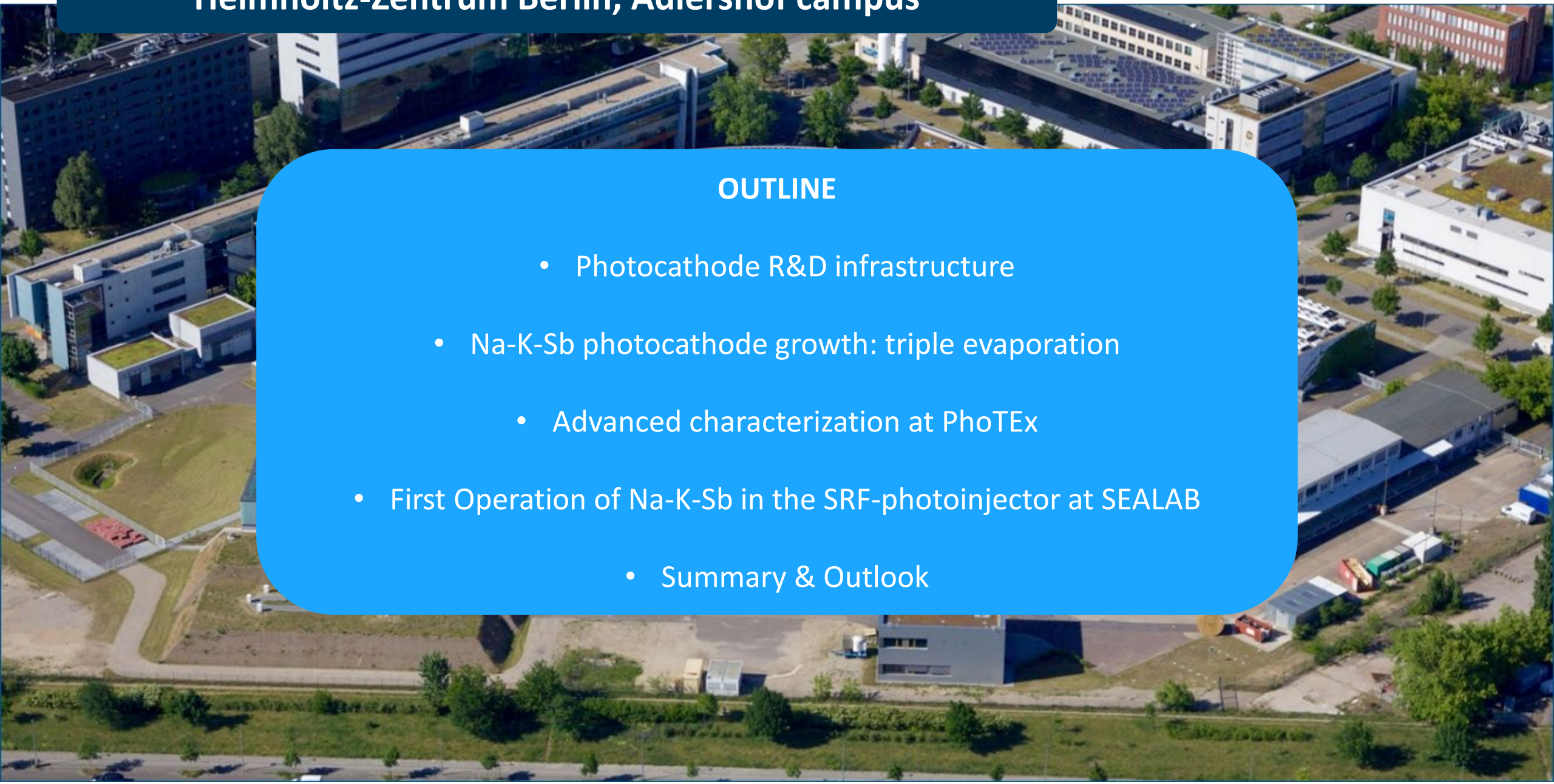
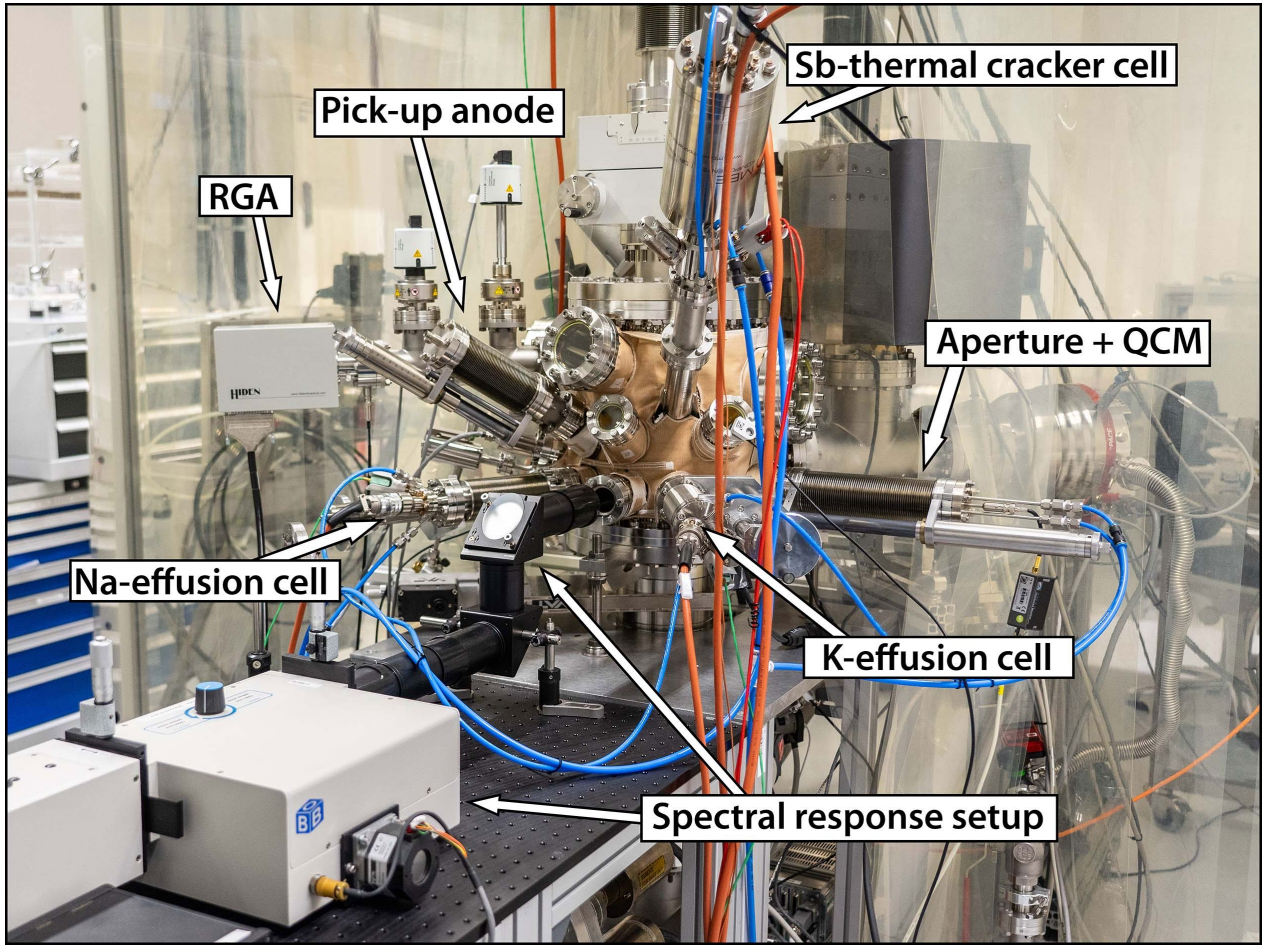
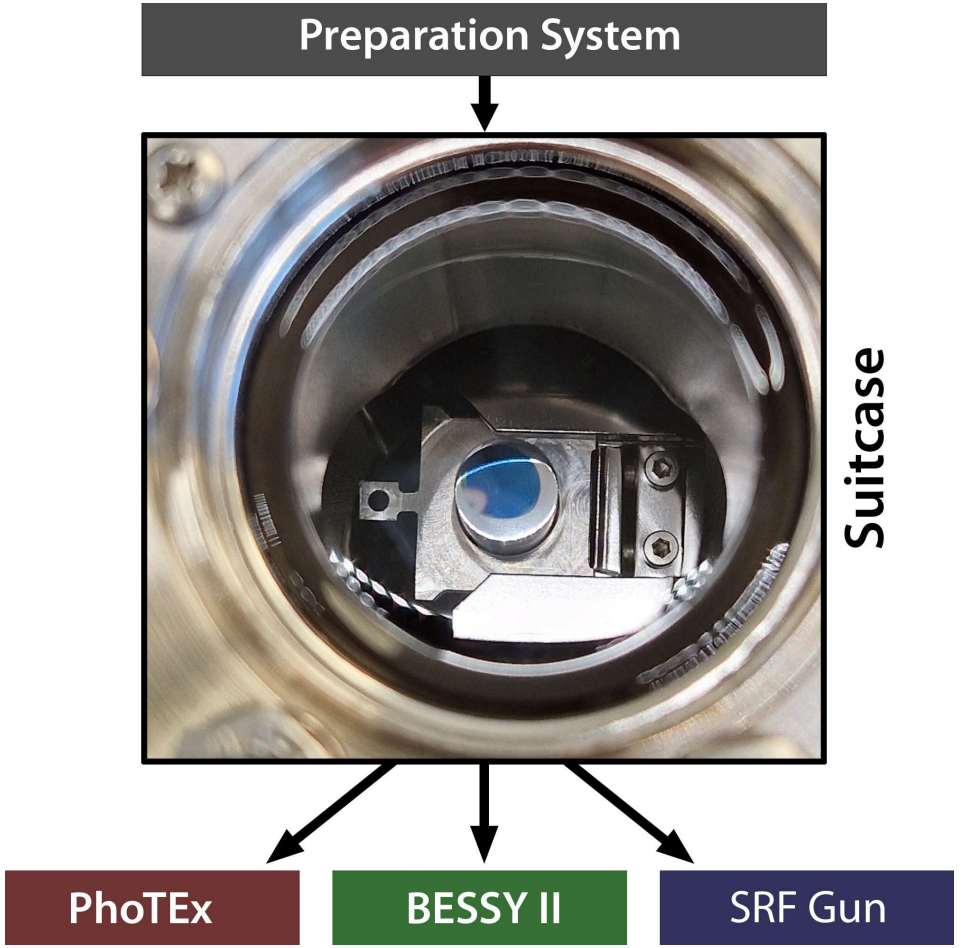
# Helmholtz-Zentrum Berlin, Adlershof campus



## OUTLINE

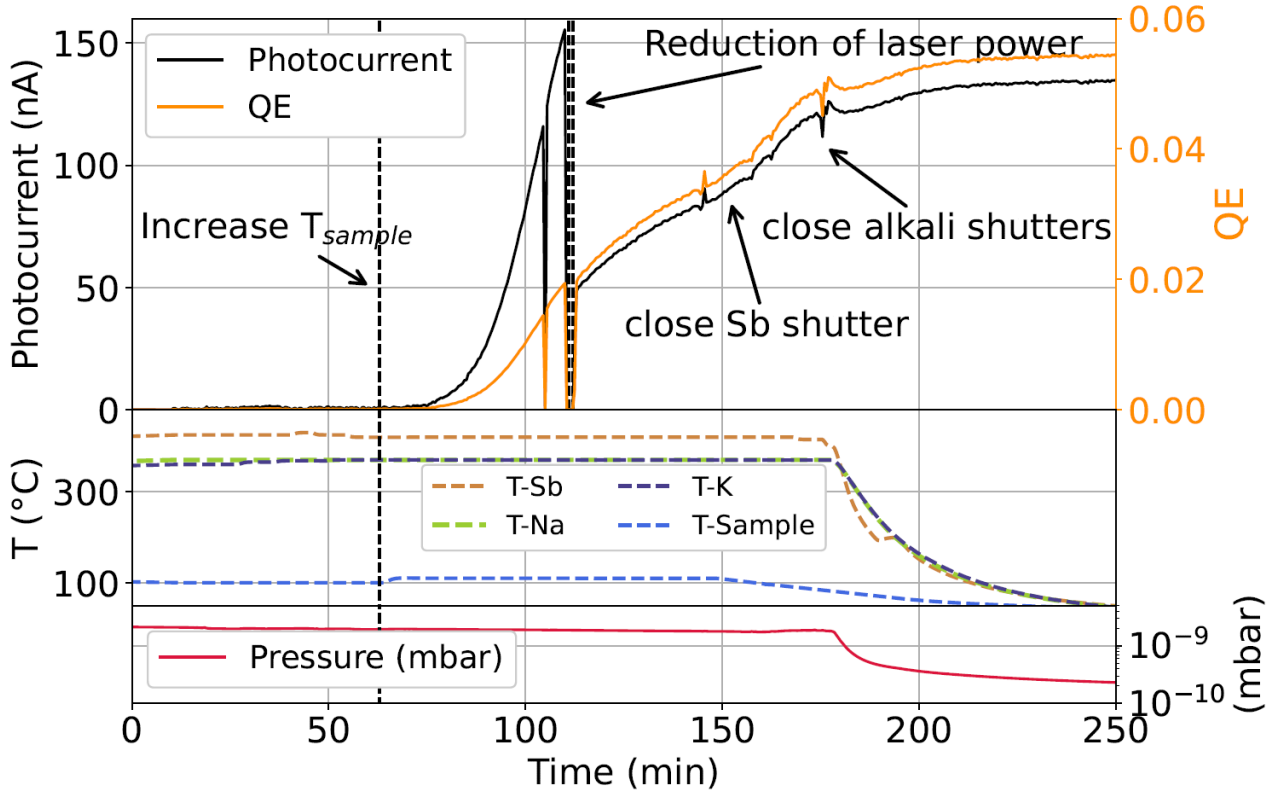
- Photocathode R&D infrastructure
- Na-K-Sb photocathode growth: triple evaporation
- Advanced characterization at PhoTEx
- First Operation of Na-K-Sb in the SRF-photoinjector at SEALAB
- Summary & Outlook




- below: In-situ X-ray photoelectron spectroscopy (XPS)

## Frist attempt of triple evaporation growth of Na-K-Sb




- growth recipe of TWH013

## SAES Alkamax pills 6-3

- Na, K
- 5 per effusion cell
- stable in air

**Dube et al., Triple Evaporation Growth and Photoemission Characterization of Bialkali Antimonide Photocathodes, Journal of Applied Physics, 2025-07-04, accepted, arXiv:2503.03573**

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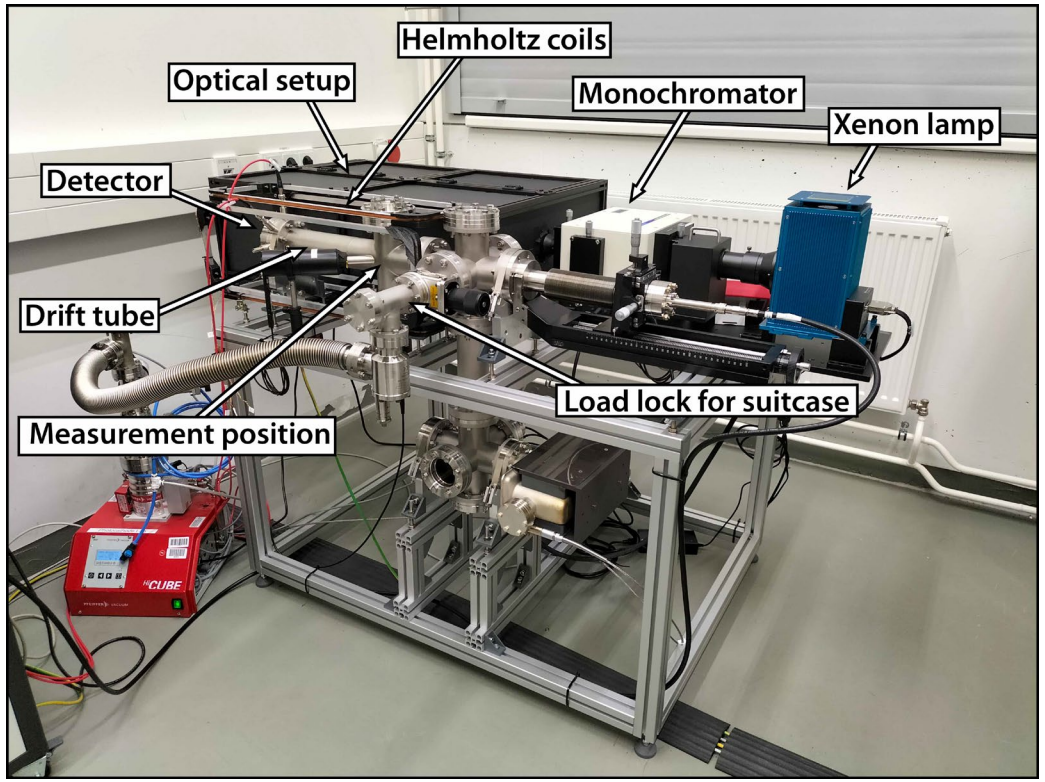
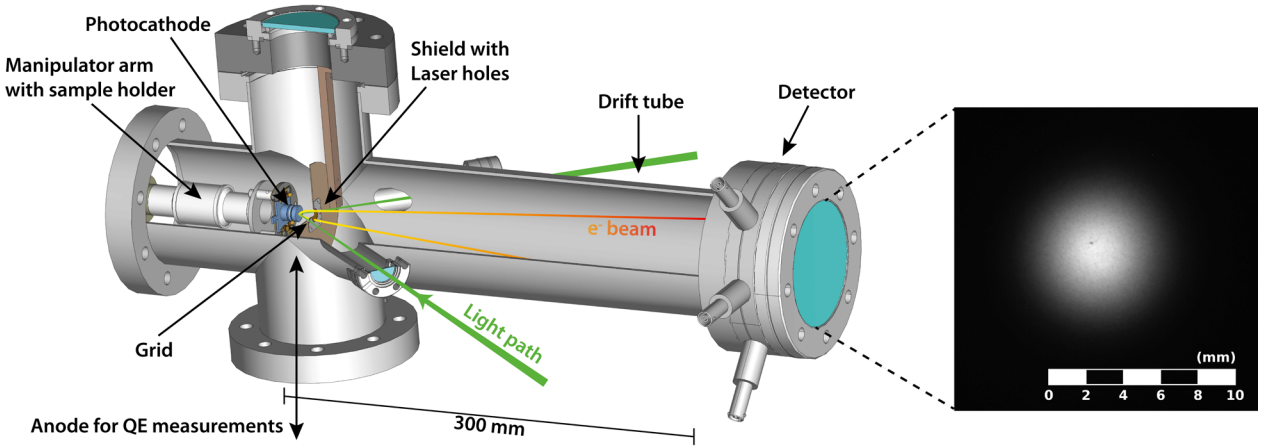
# The Photoemission and Transverse Energy Experiment - PhoTEx

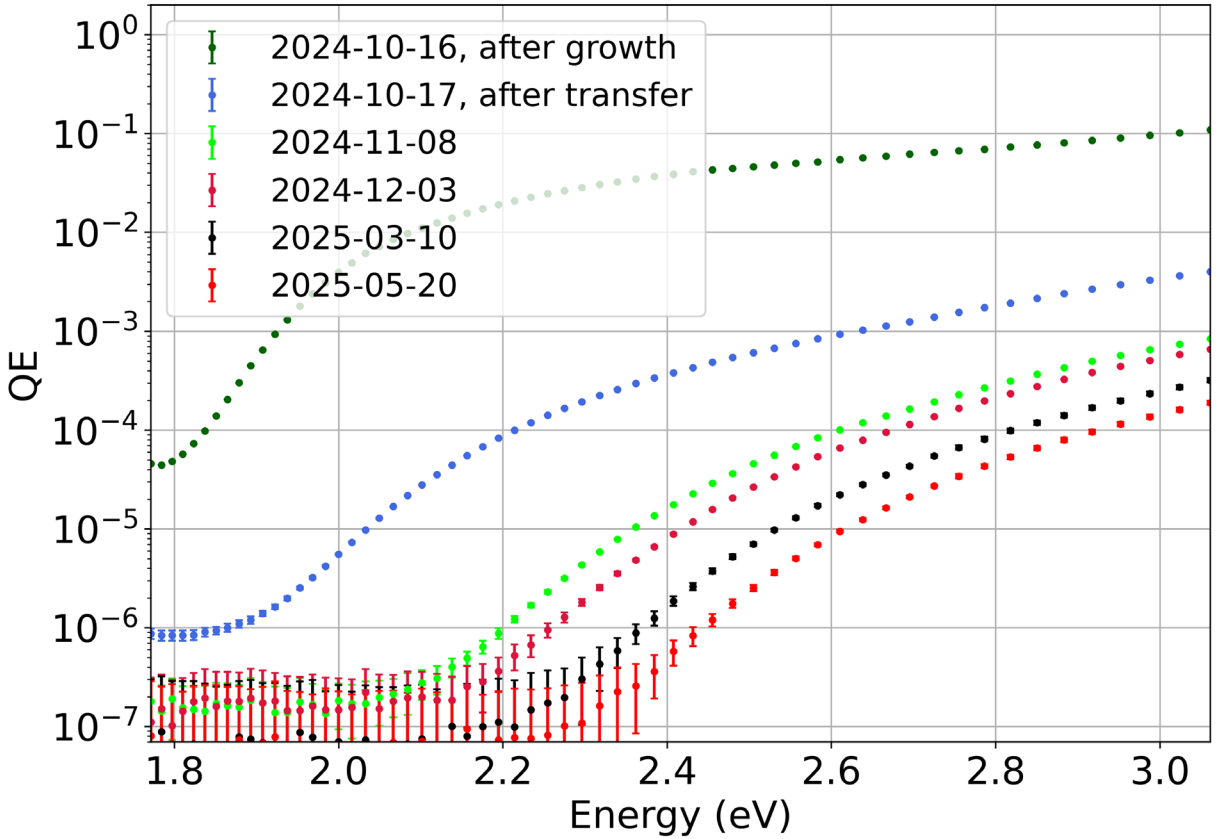


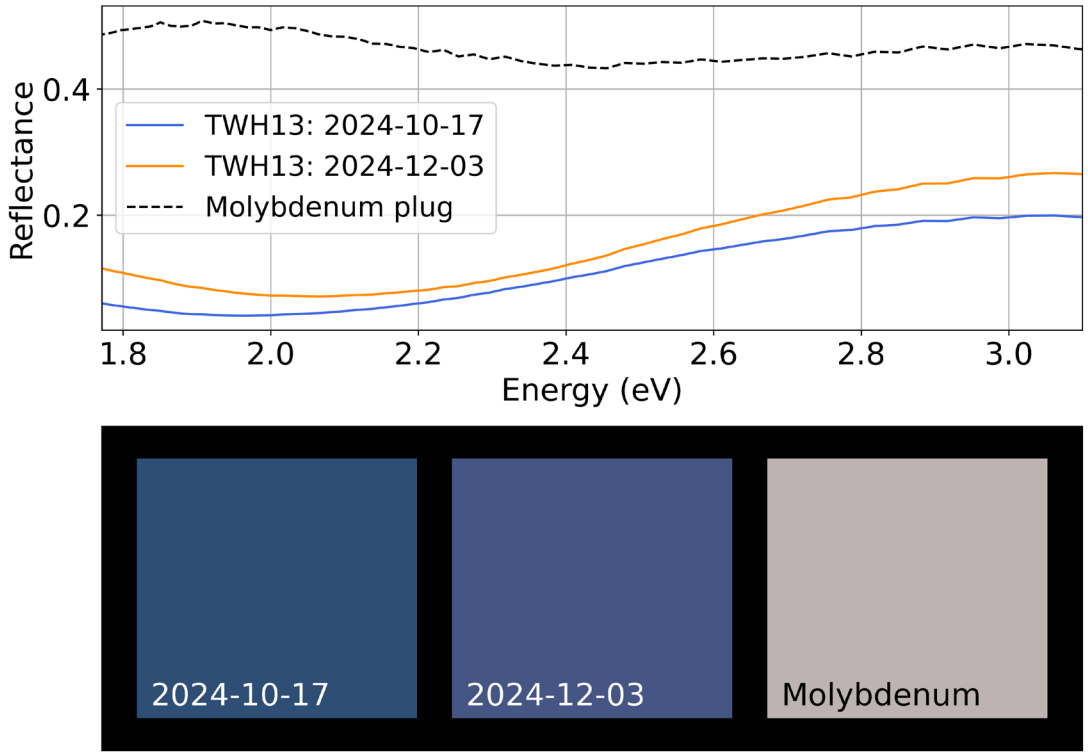

- PhoTEx assembled in the MTE laboratory




- 3D model of the analysis chamber and real image of an electron beam at the detector

**Dube et al., Triple Evaporation Growth and Photoemission Characterization of Bialkali Antimonide Photocathodes, Journal of Applied Physics, 2025-07-04, accepted, arXiv:2503.03573**

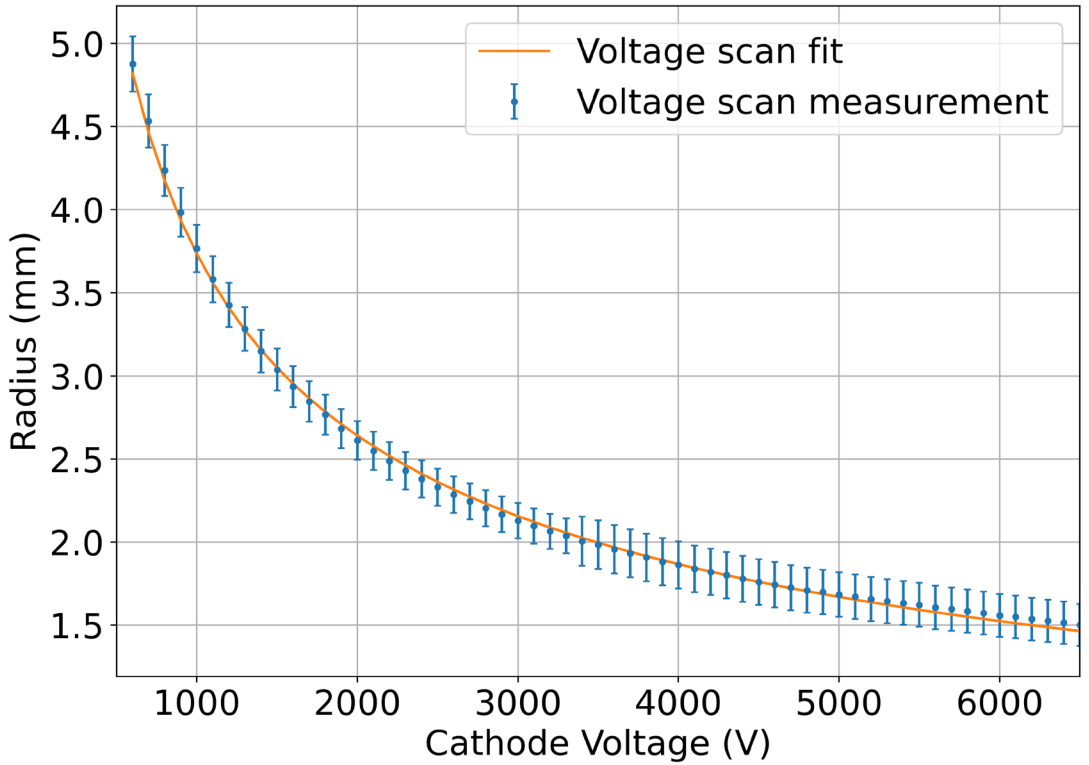


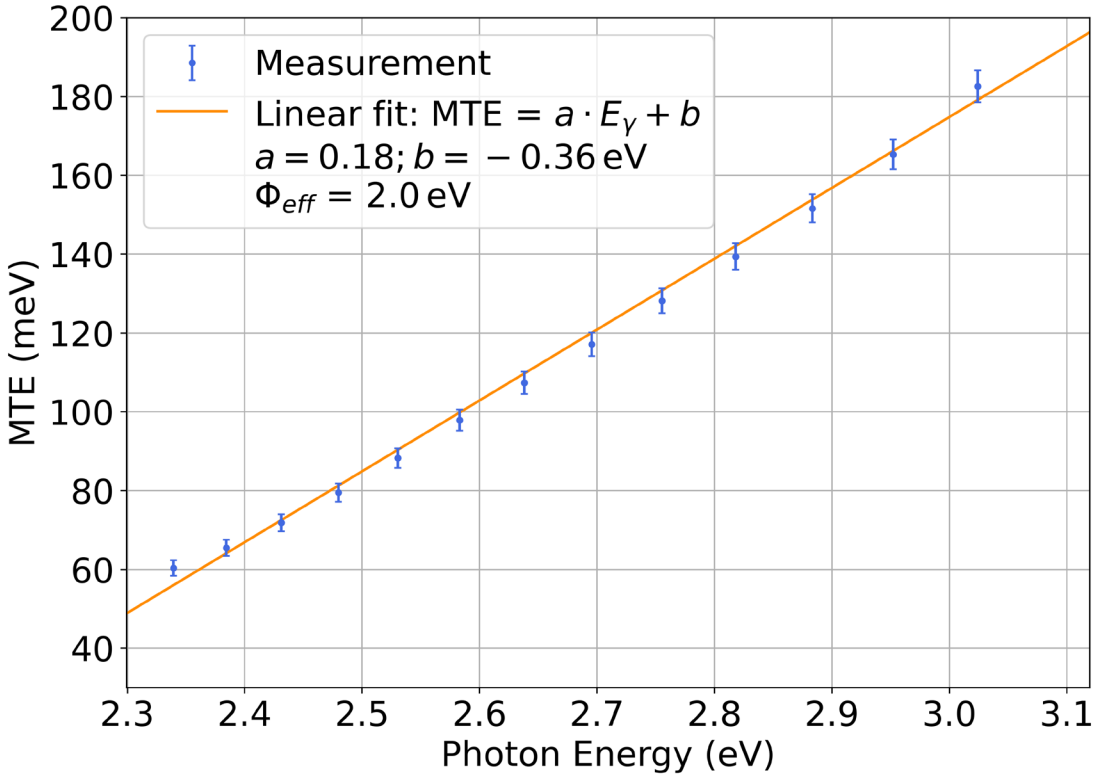




- spectral response curves of the photocathode TWH013

- reflectance curves of the photocathode TWH013 (top)
- photocathode color was determined from reflectance

**Dube et al., Triple Evaporation Growth and Photoemission Characterization of Bialkali Antimonide Photocathodes, Journal of Applied Physics, 2025-07-04, accepted, arXiv:2503.03573**




- Voltage scan of TWH013
- MTE @ 450nm about 135 meV

- Wavelength scan of photocathode TWH013

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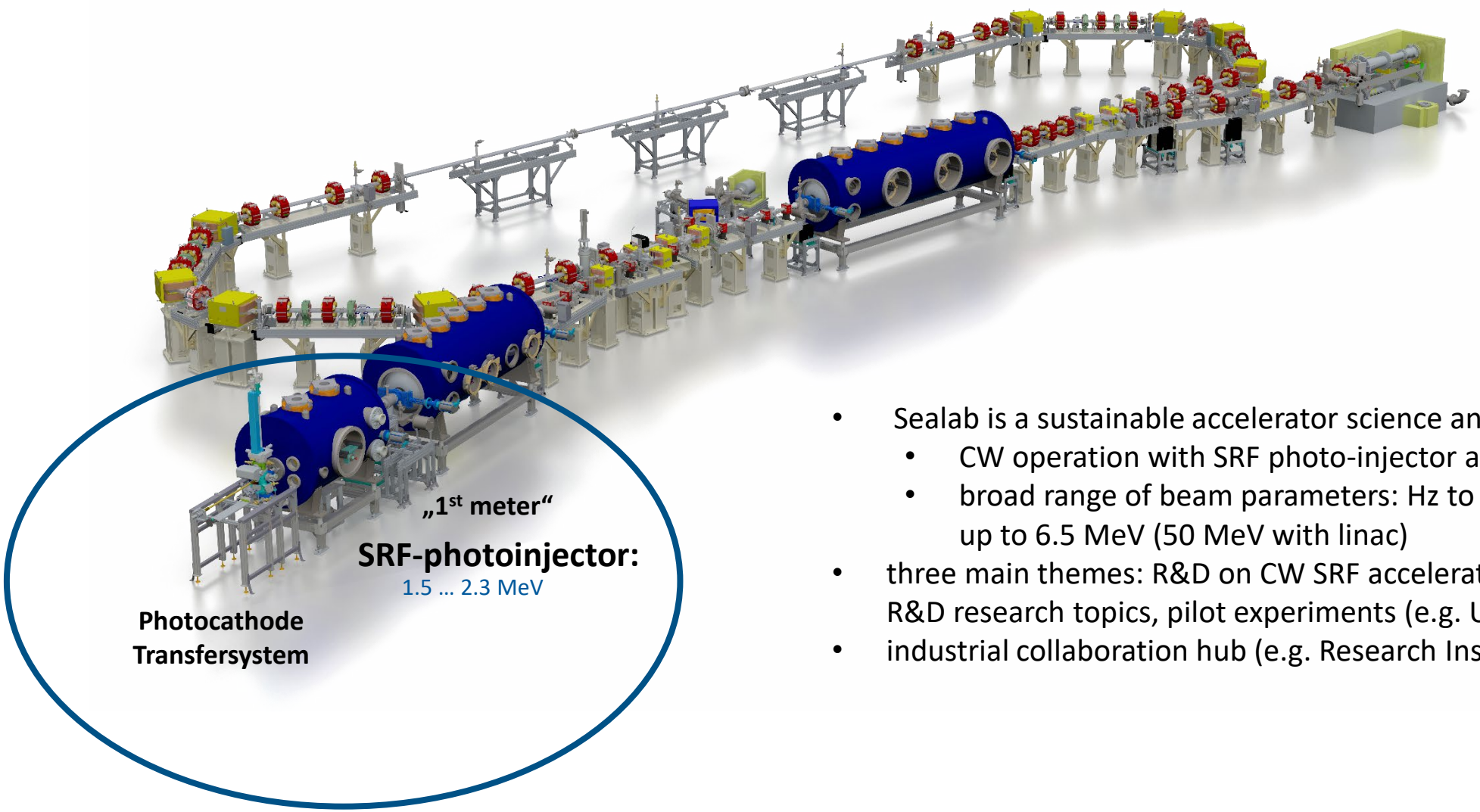
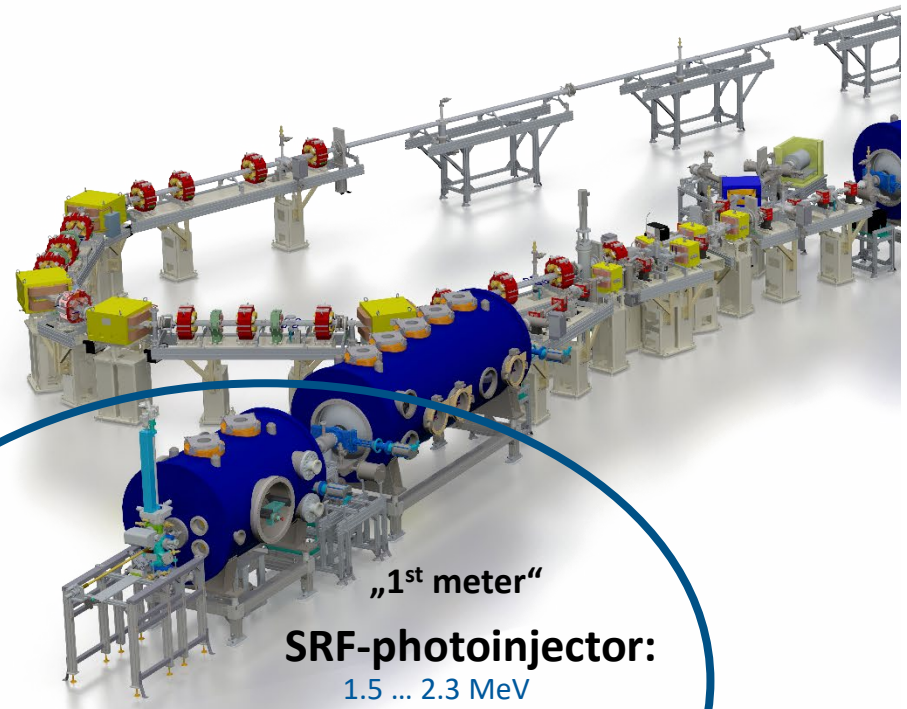



Supralab
SEALAB
From Materials to Beam

- Sealab is a sustainable accelerator science and applications laboratory
  - CW operation with SRF photo-injector and SRF accelerating systems
  - broad range of beam parameters: Hz to GHz, fC to nC, fs to ps, up to 6.5 MeV (50 MeV with linac)
- three main themes: R&D on CW SRF accelerating systems, Accelerator R&D research topics, pilot experiments (e.g. UED)
- industrial collaboration hub (e.g. Research Instruments)

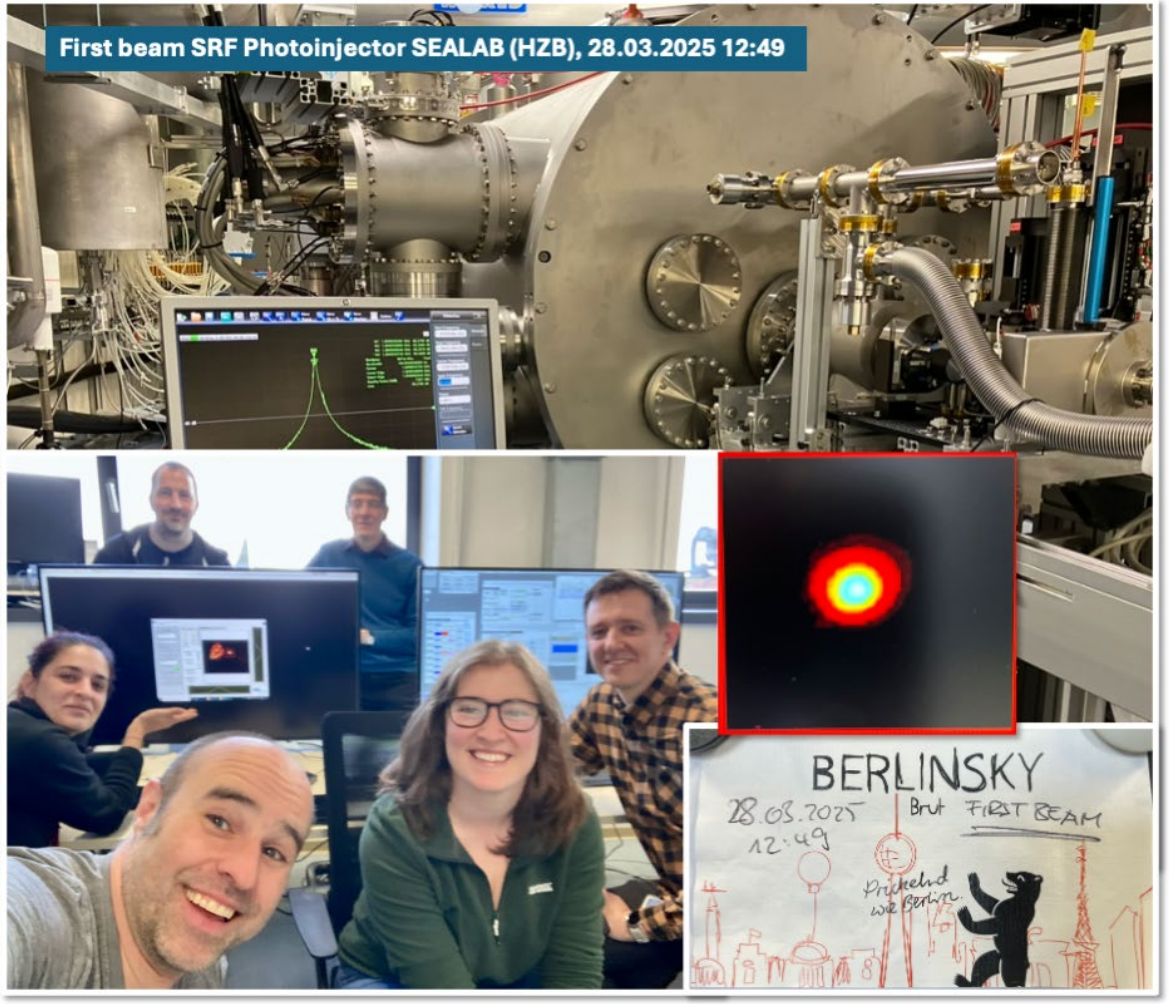


„1st meter“

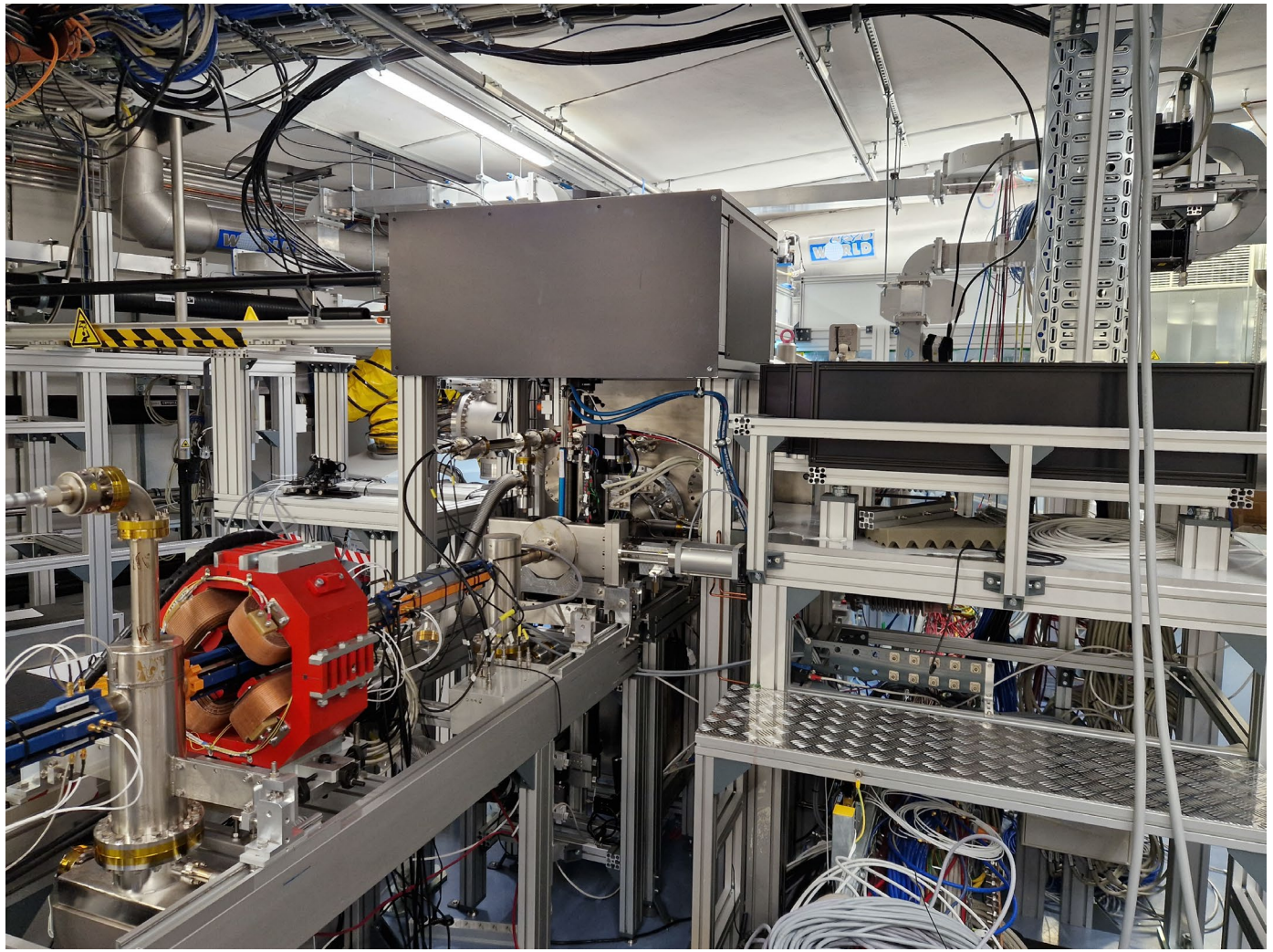
**SRF-photoinjector:**
1.5 … 2.3 MeV

**Photocathode**
**Transfersystem**

**First beam in March 2025!**

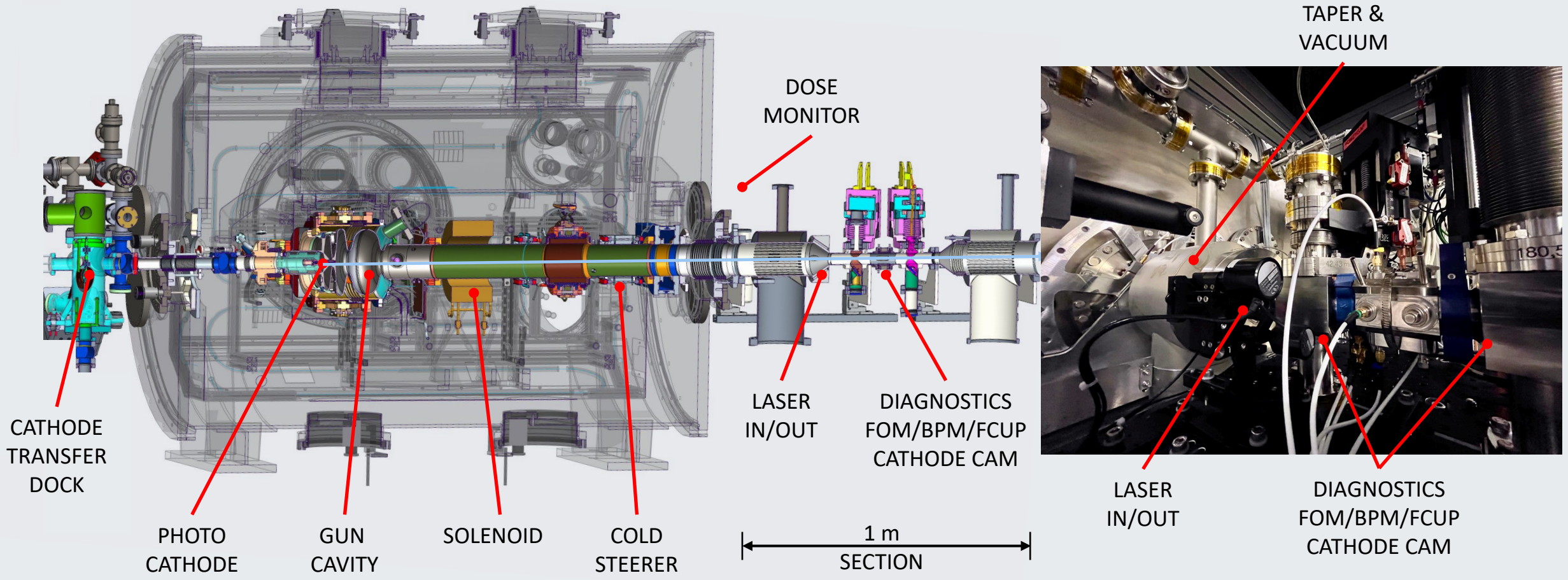



**KAMPS et al., FIRST BEAM COMMISSIONING OF THE HZB SRF PHOTOELECTRON GUN, IPAC 2025, WECN2.**

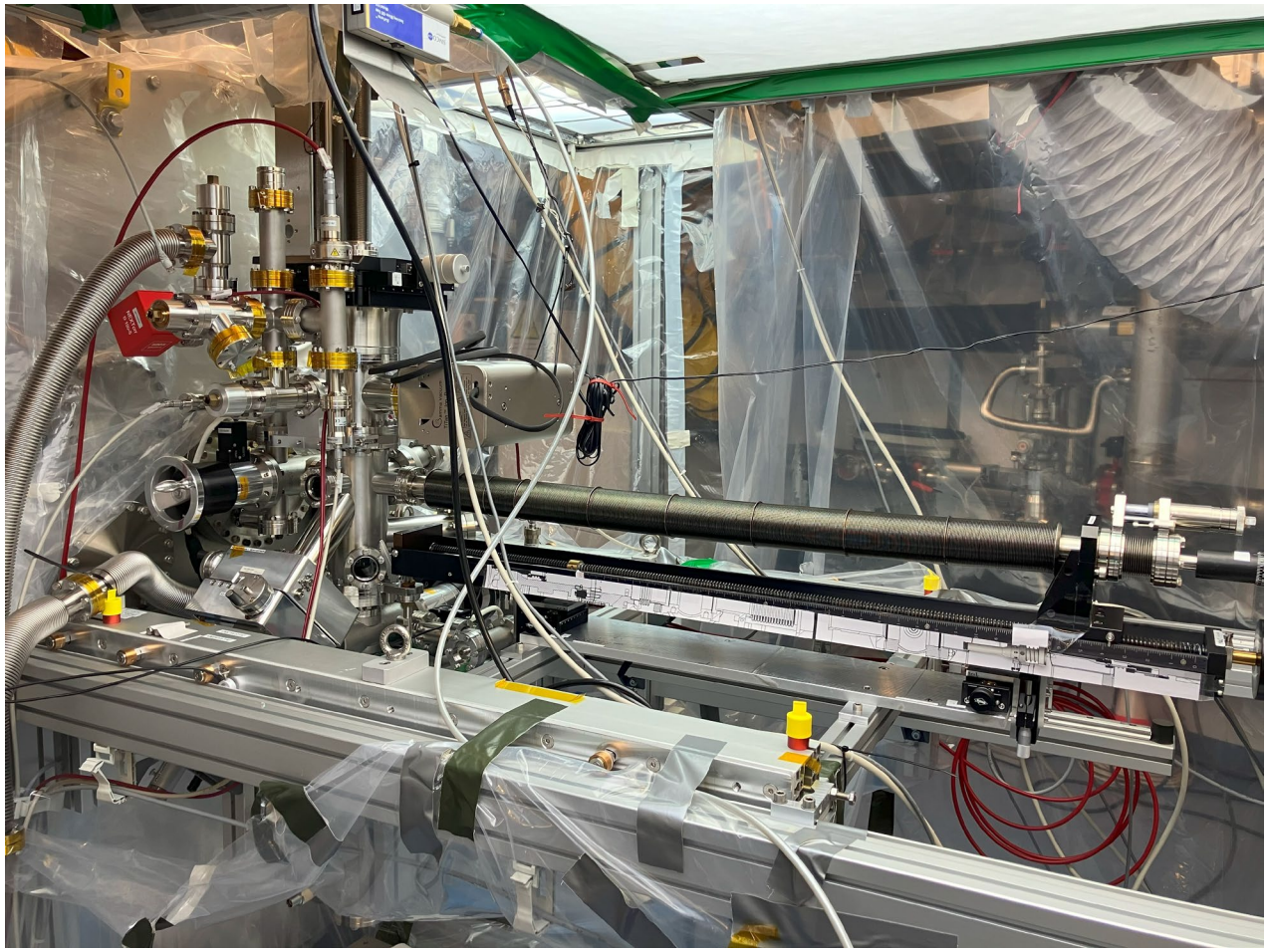


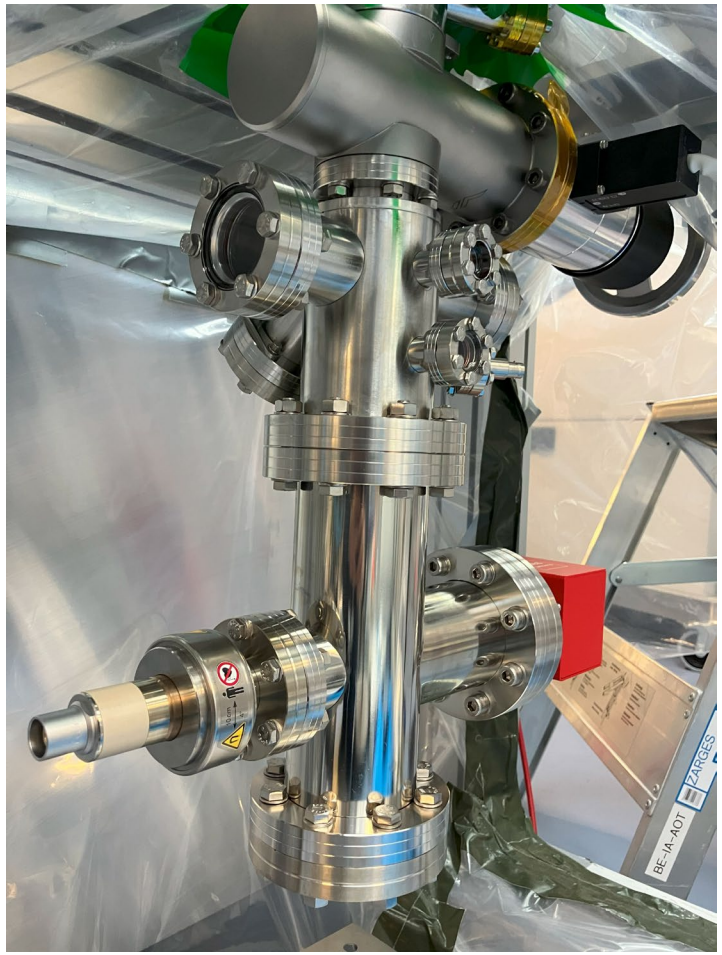
- Front view SRF-photoinjector at SEALAB: „first meter“ and laser

SRF GUN MODULE WITH PHOTOCATHODE TRANSFER AND FIRST DIAGNOSTICS




- Cross section of the SRF-photoinjector at SEALAB and “first meter”

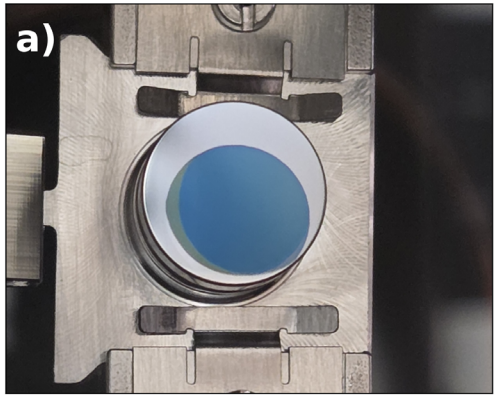




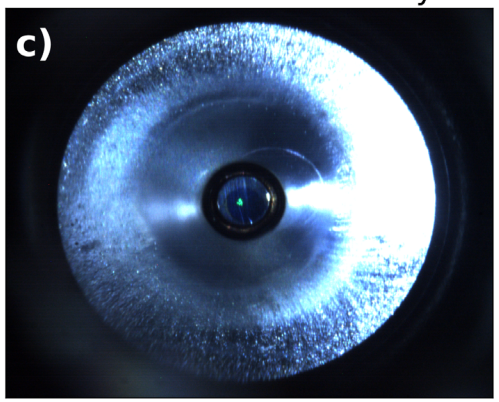
- Back view: Photocathode transfer system (p < 6E-10 mbar)
- vacuum suitcase (p < 1E-10 mbar)

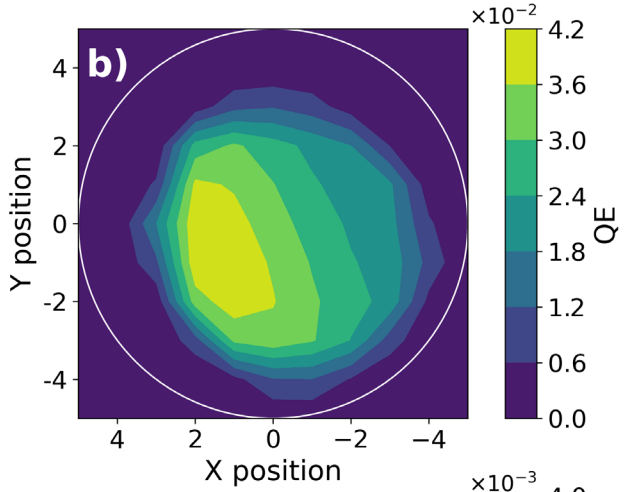
**KÜHN, J. et al., UHV Photocathode Plug Transfer Chain for the bERLinPro SRF-Photoinjector, IPAC 2017, TUPAB029.**

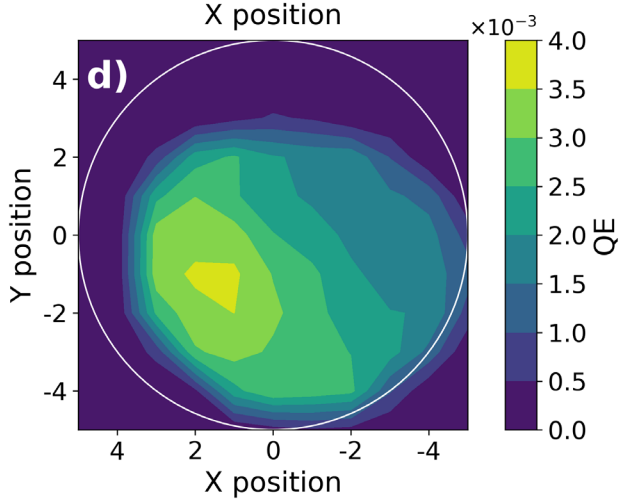
SEA02 in Photocathode Lab

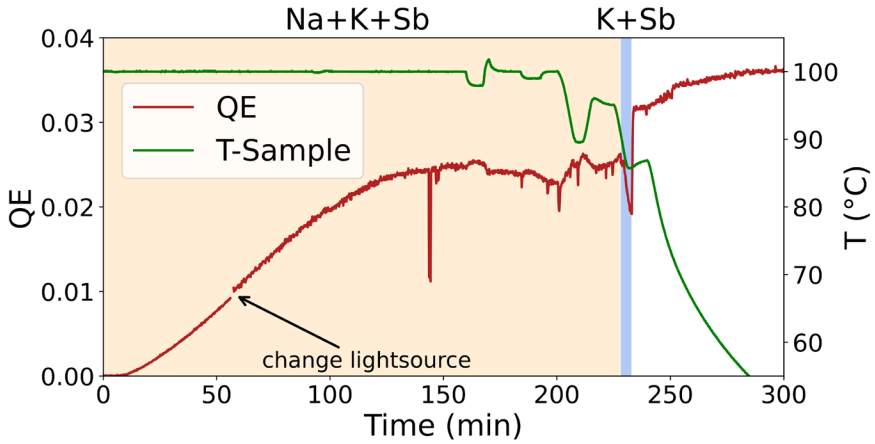



SEA02 in the SRF cavity

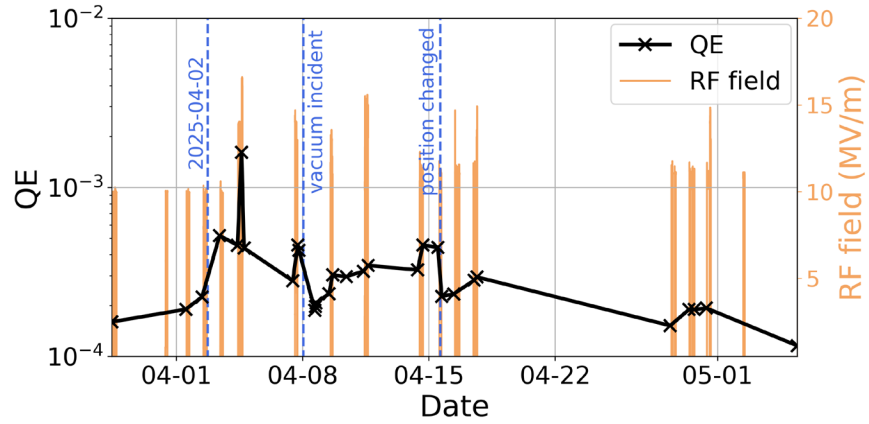


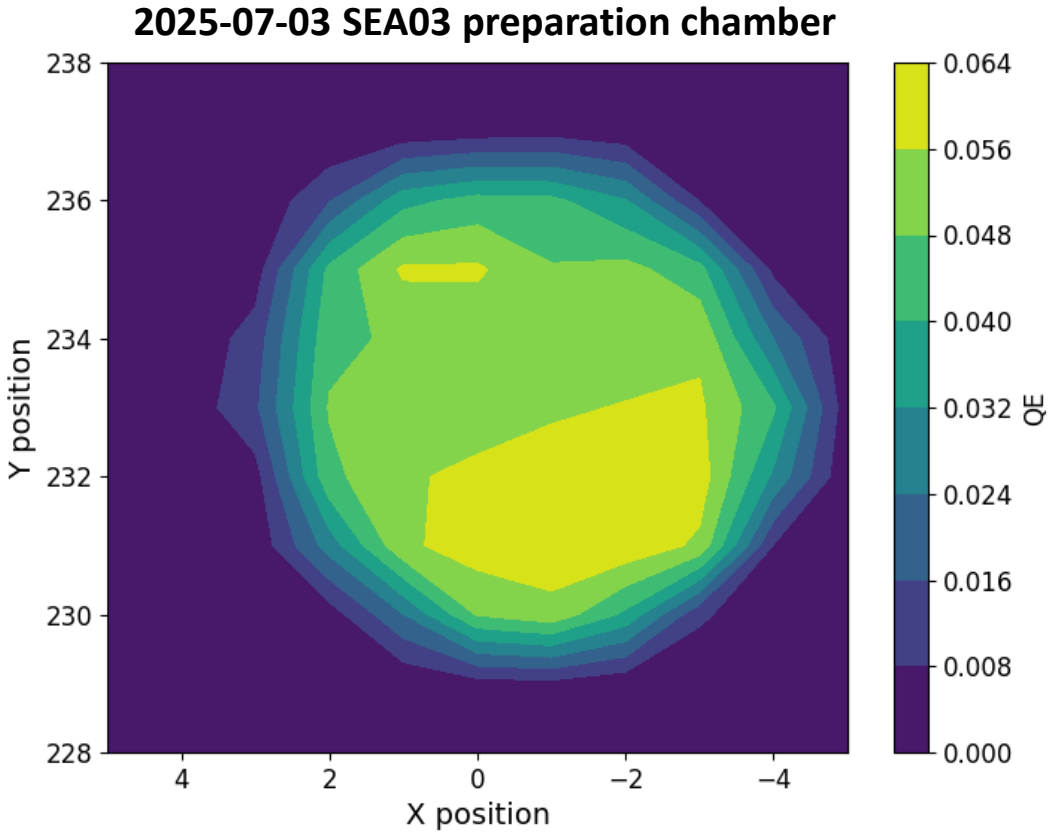

- SEA02 growth

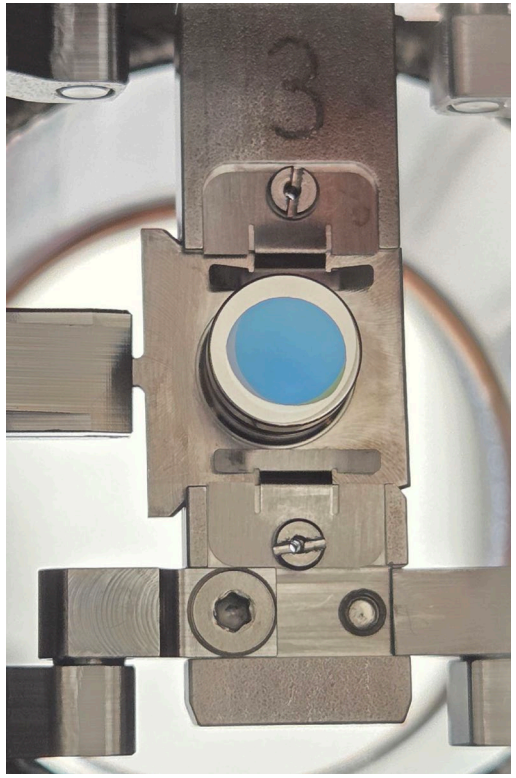


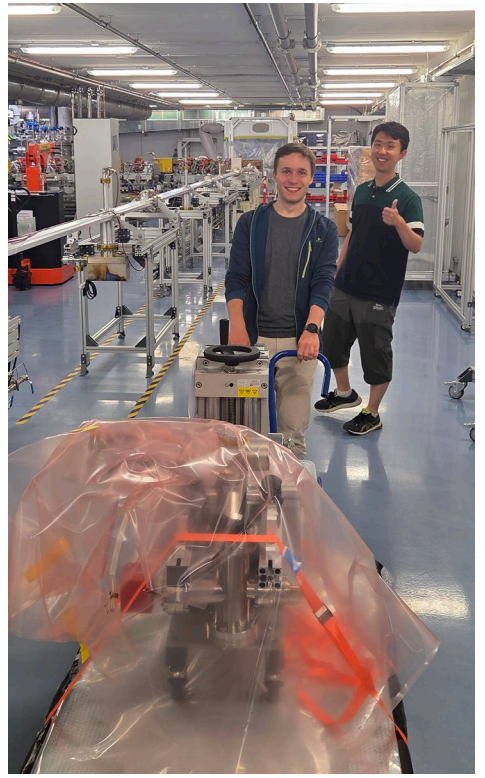

- Photocathode and QE map in the preparation system (top)
- Photocathode and QE map in SRF-photoinjector (bottom)

- SEA02 in operation

**KAMPS et al., FIRST BEAM COMMISSIONING OF THE HZB SRF PHOTOELECTRON GUN, IPAC 2025, WECN2.**





- third photocathode grown after refilling the effusion cells and bake-out
- QE above 5% at 520 nm and more homogenous

- transferred to SEALAB and installation pending

- developed a triple evaporation growth process of Na-K-Sb photocathodes
  - using effusion cells with SAES Alkamax pills for Na and K
  - over 20 photocathode w/o breaking the vacuum
  - high and homogeneous QE, high reproducibility, long lifetime

- successful commissioning of the PHOTEX system: MTE, QE and reflectivity
  - waiting for more photocathodes
  - upgraded with an RGA to study oxygen poisoning

- SRF-gun commissioning on-going at SEALAB
  - first successful operation of a Na-K-Sb photocathode in an SRF-photoinjector
  - next run in preparation

- vacuum suitcase ready to transport sample to BESSY II and other systems
  - next beamtime scheduled in December 2024

- Jonas Dube and Chen Wang for their work in the lab and for SEALAB
- Alice Galdi supporting growth and beam time, Universita degli Studi di Salerno, Italy
- Caterina Cocchi and team for their theoretical work, University of Jena, Germany
- Michael Schuster and André Frahm from the SRF group supporting the cathode transfer, HZB
- SEALAB team and support by different BESSY II groups for getting the SRF-photoinjector running, HZB
- Lee Jones, UKRI STFC Daresbury Lab, UK
- Daniele Sertore, INFN Lasa, Italy
- Rong Xiang, HZRD, Germany


# Thank you for your attention!