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Bundesministerium
für Bildung
und Forschung


CHyN
Centre for Hybrid Nanostructures

# Successful SIS multilayer activities on cavities and samples using ALD

Marc Wenskat on behalf of our SRF R&D Team

# SIS multilayers (PE)-ALD investigation at UHH

## Thermal ALD: $Al_2O_3$

*Capability for coating* *single-cell cavities*

## PEALD: AlN, NbTiN, NbN

*Capability for coating* *planar samples*

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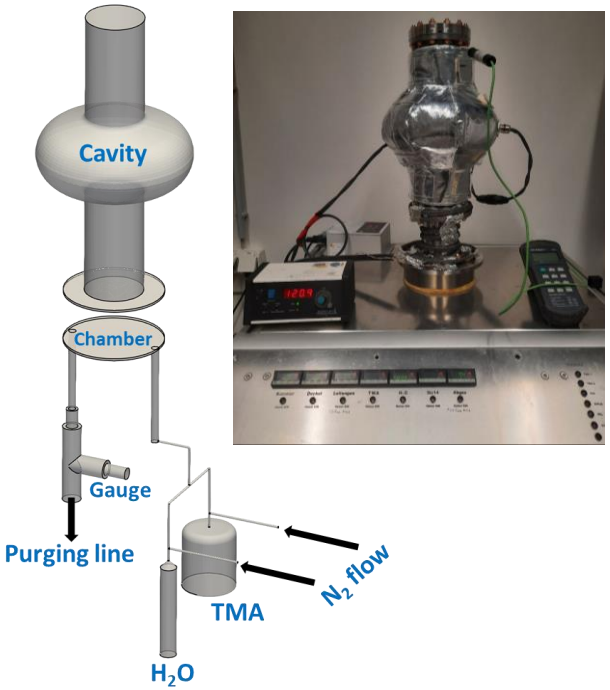
- ✓ **Proof-of-principle experiment**
  - Process optimization
  - Thermal ALD Process Simulation

## Thermal ALD setup



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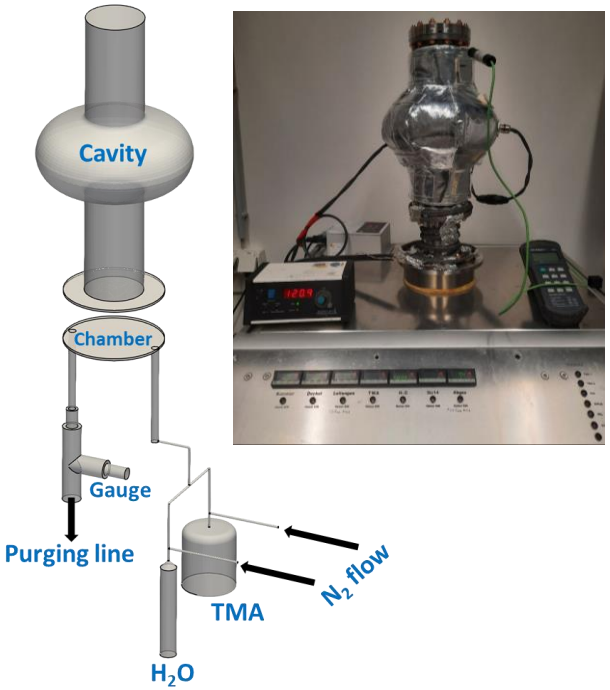




## Process optimization

| | |
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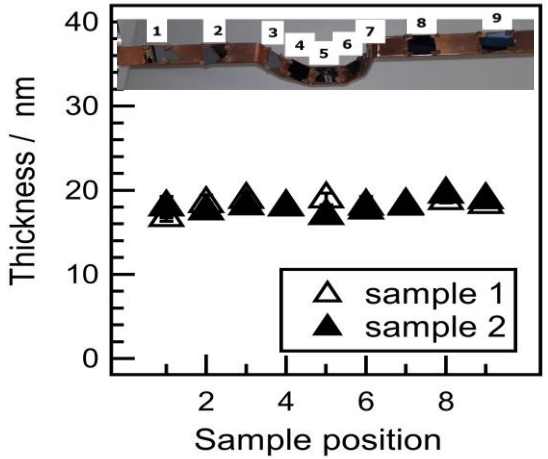
| Precursors | TMA/$H_2O$ |
| Temp. | 120 °C |
| Thickness | ~18 nm |



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- ✓ **Gradients above 40MV/m without any deterioration in Q-value**

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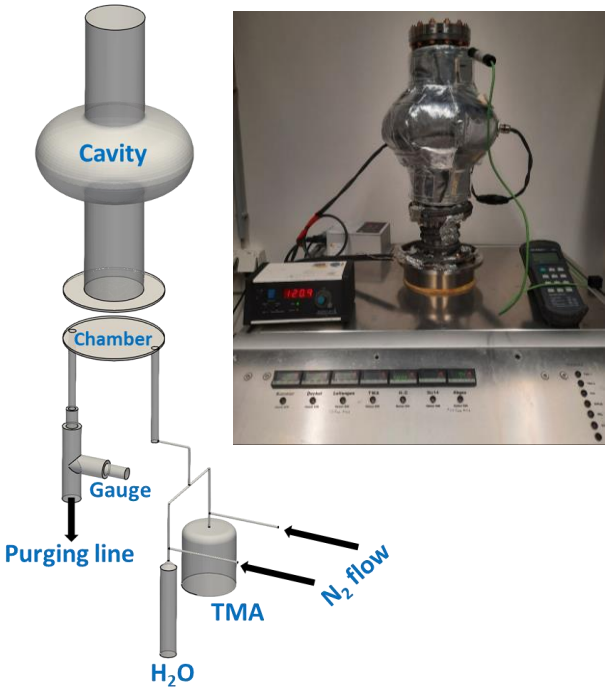


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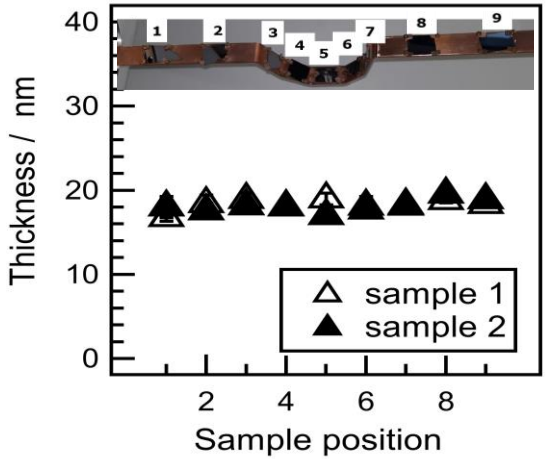
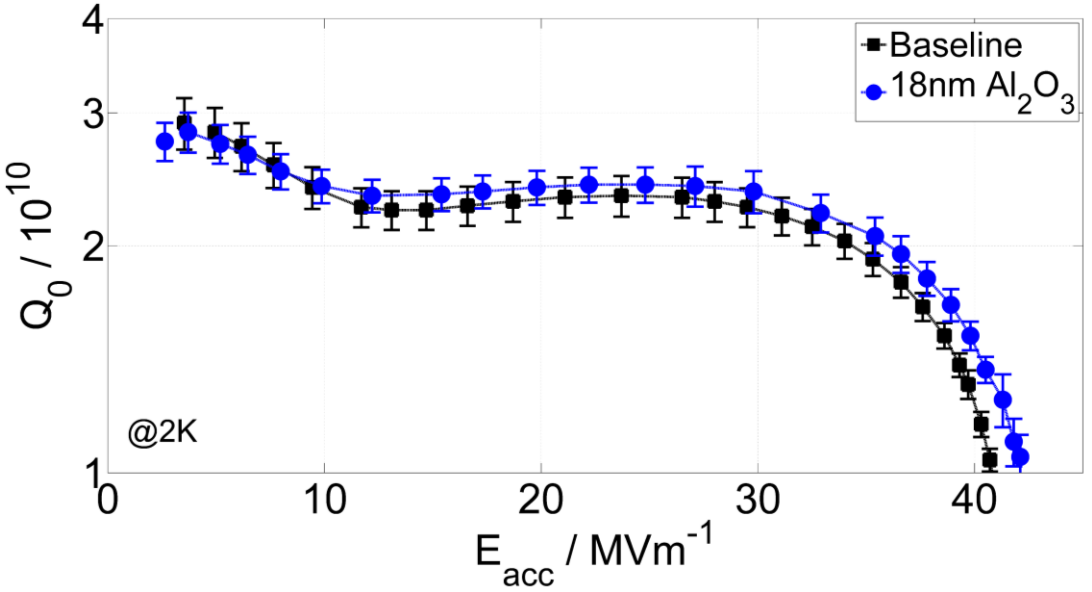



## Cavity performance





Marc Wenskat *et al* 2023 *Supercond. Sci. Technol.* **36** 015010
**DOI** 10.1088/1361-6668/aca83f

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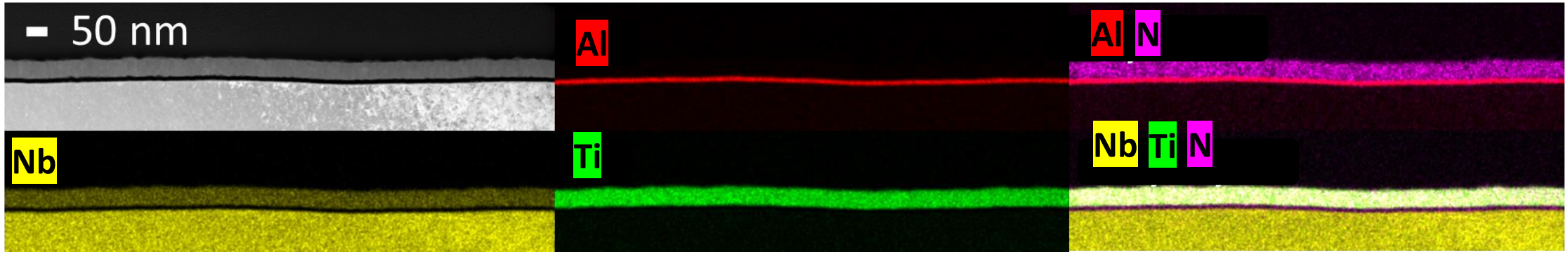
# Tailored AlN-NbTiN multilayers deposited by PEALD on Nb and Si substrates

- Elemental analysis



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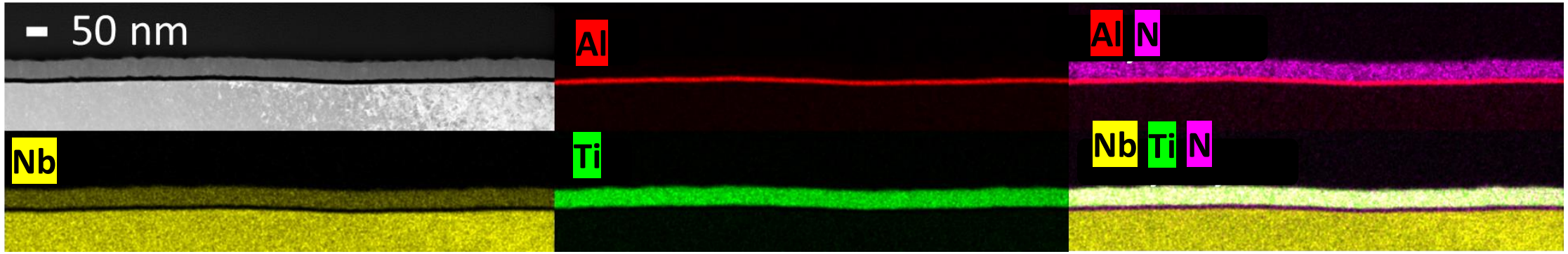


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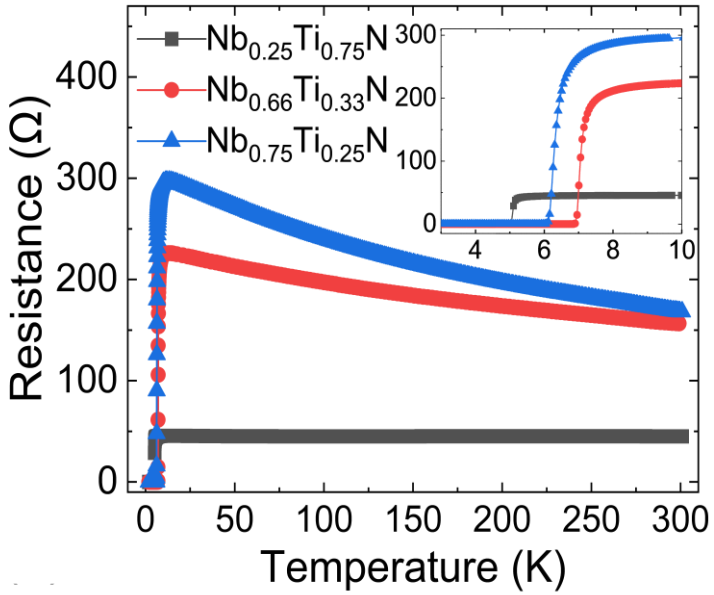

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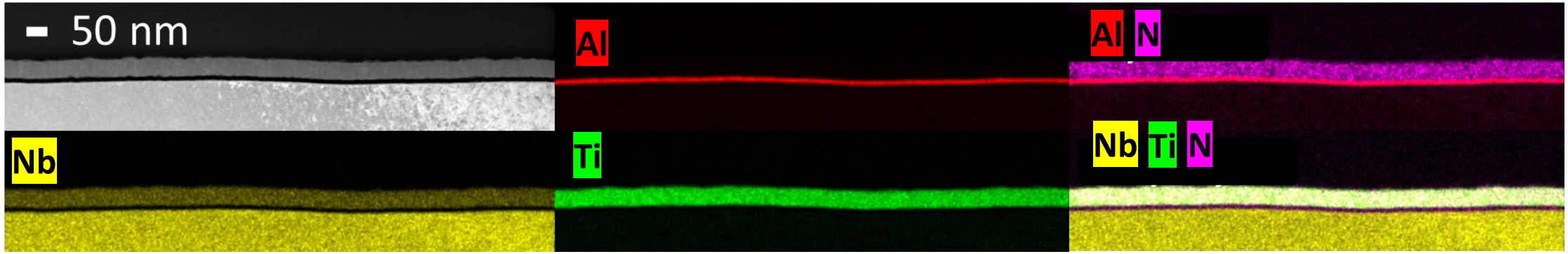


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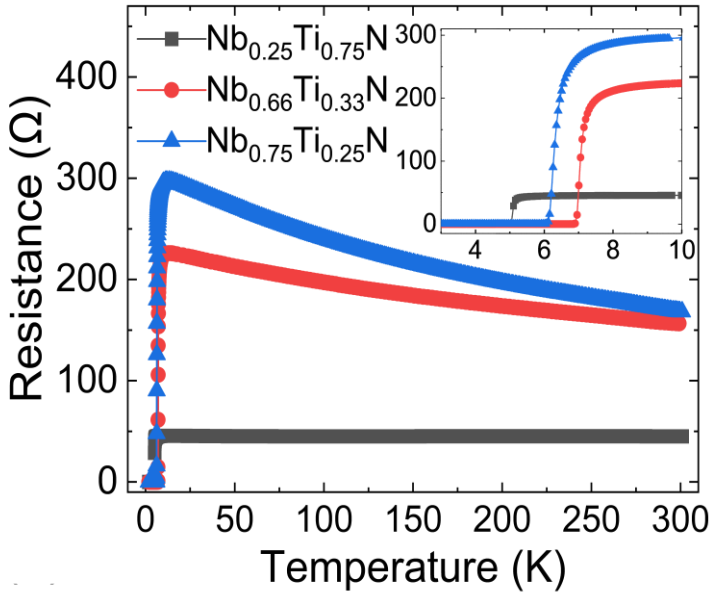
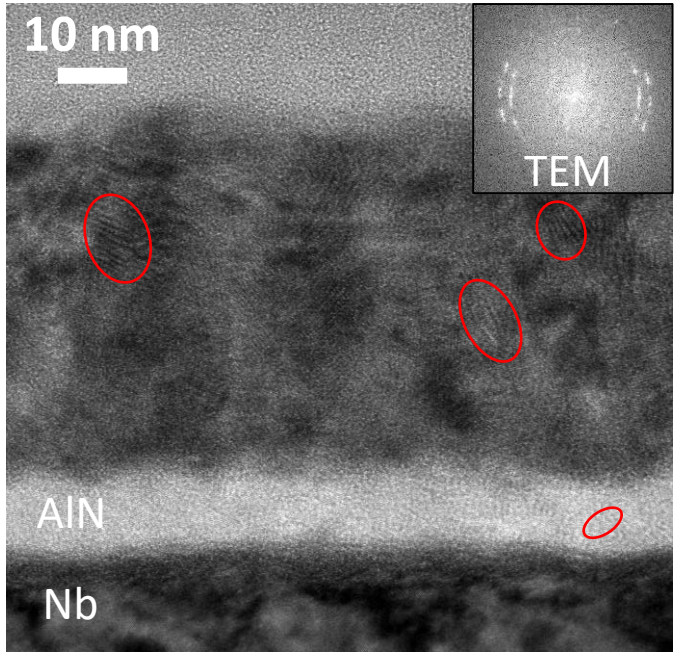



- Crystallinity



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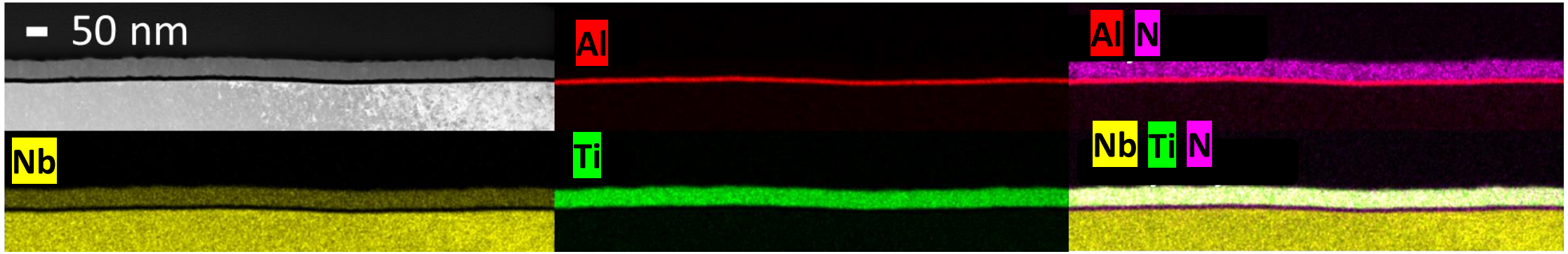


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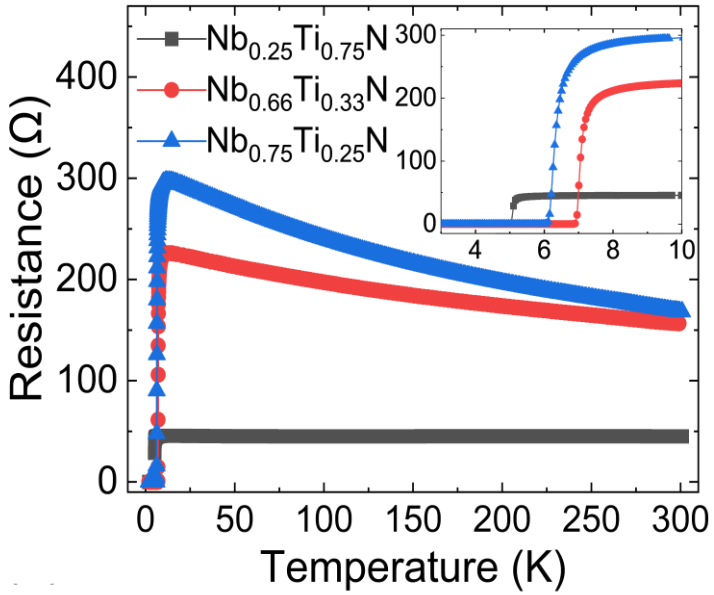


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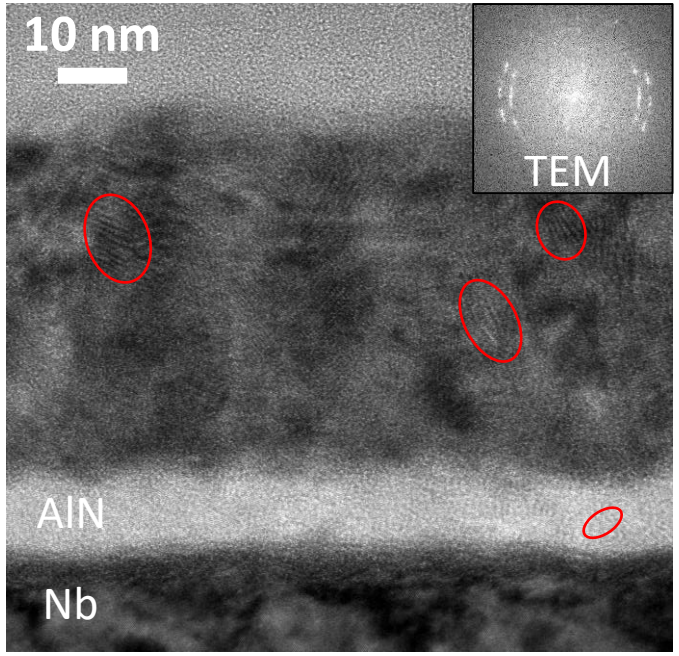
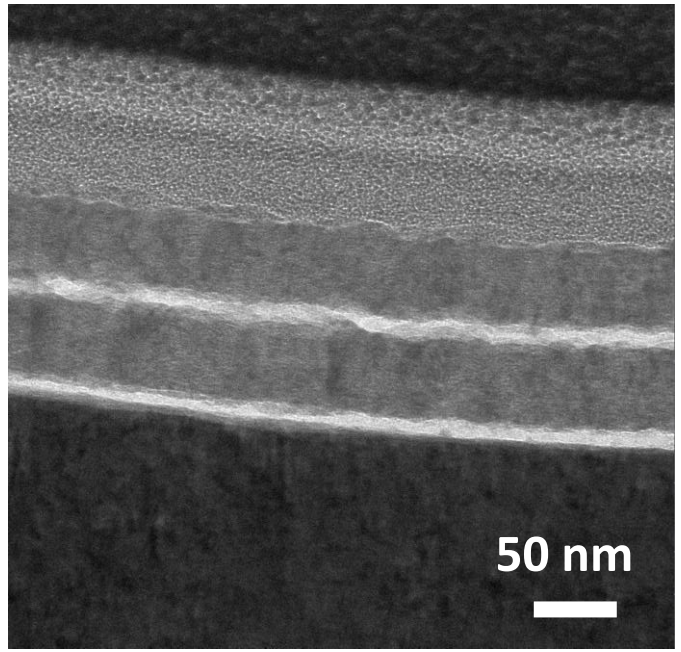



- Nb – (AlN – NbTiN) x2



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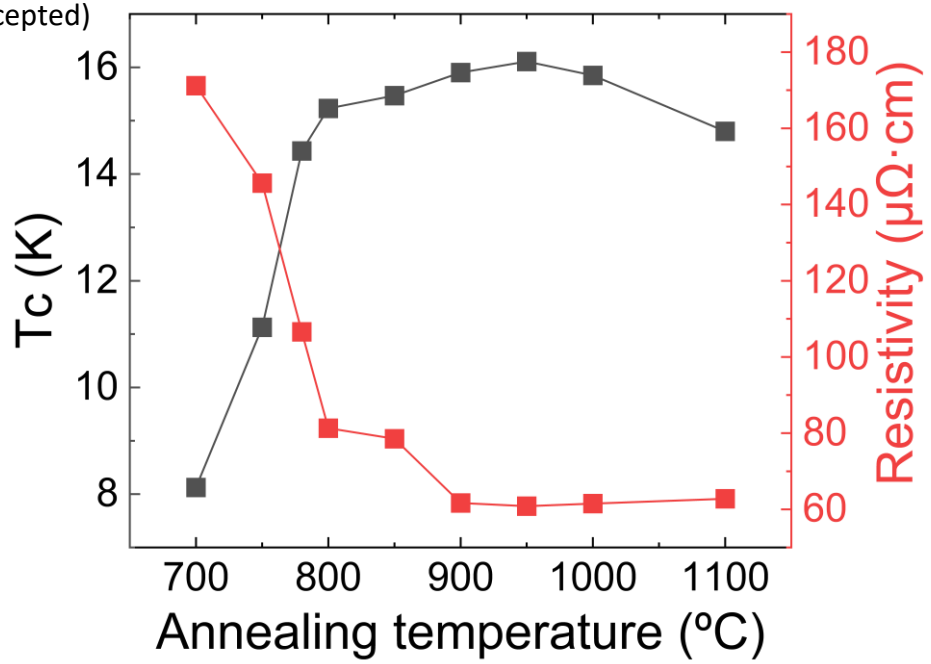
- Enhancement superconducting properties annealing AlN-NbTiN multilayers Detailed info: I. González Díaz-Palacio *et al.*, Thermal annealing of superconducting niobium titanium nitride thin films deposited by plasma-enhanced atomic layer deposition *Journal of Applied Physics* (accepted)



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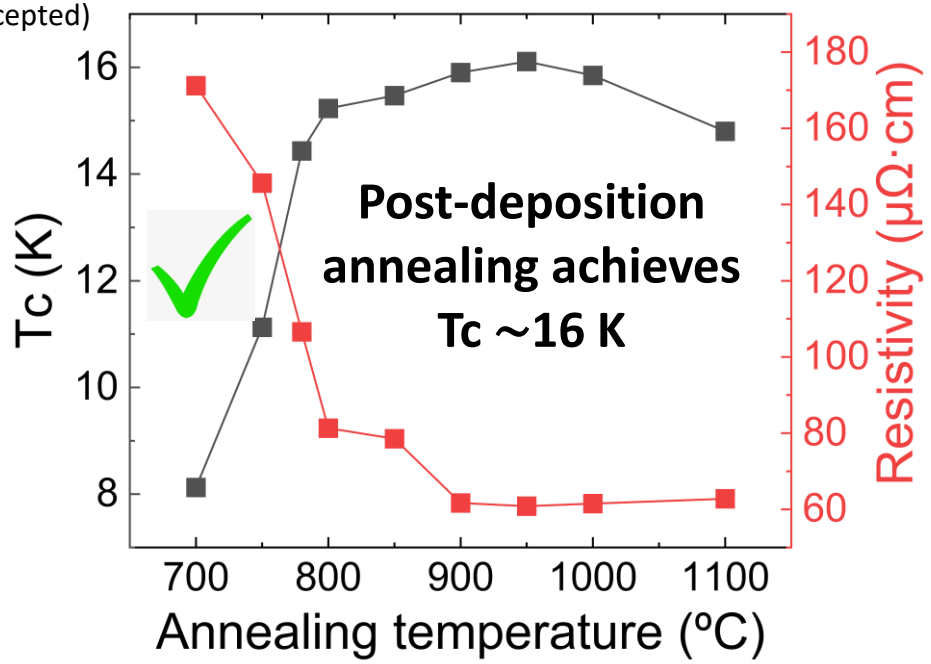

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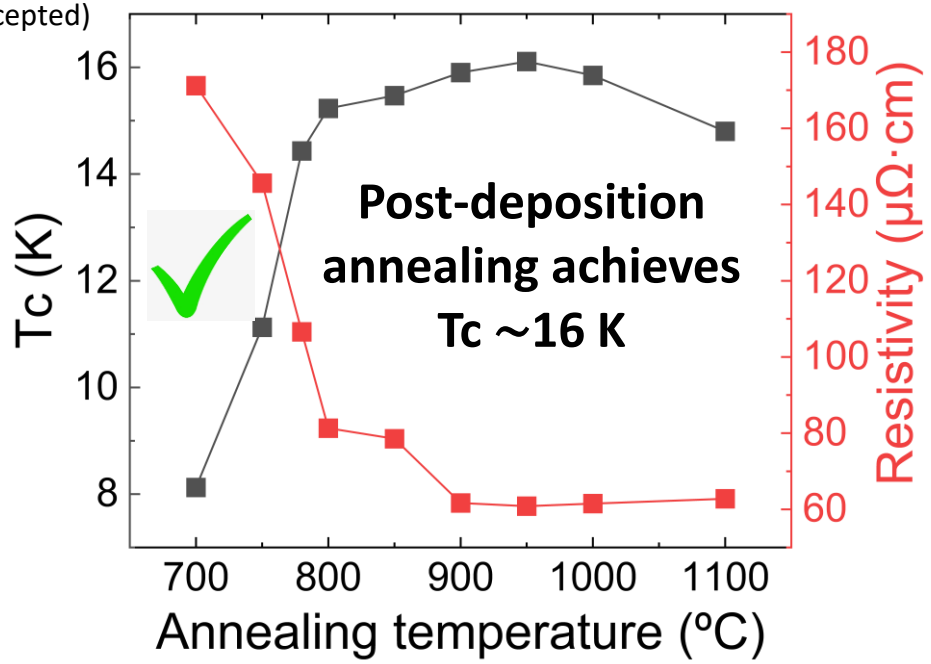


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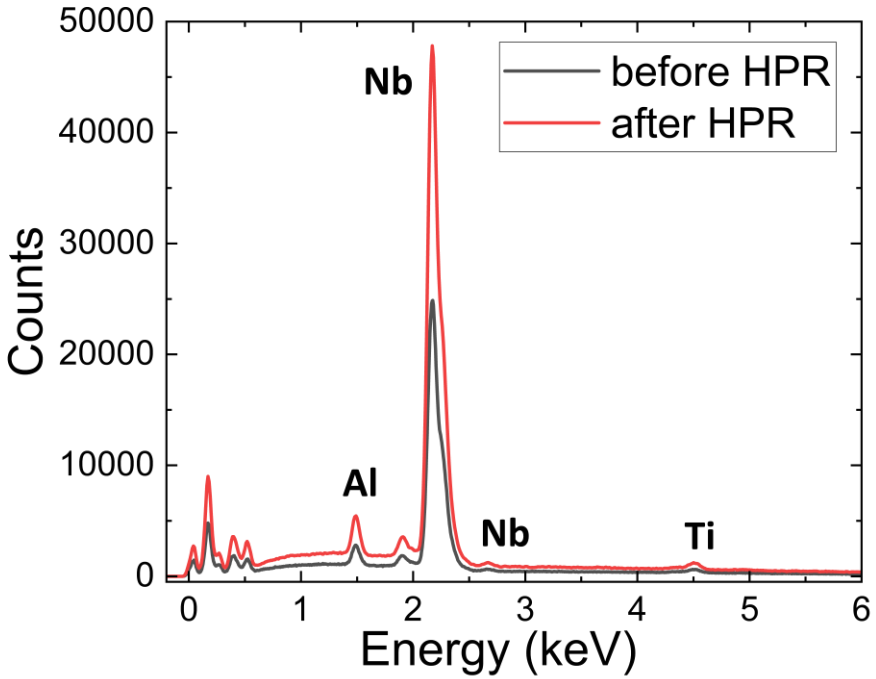


DESY facilities
Cleanroom ISO4

**Layers deposited by (PE)-ALD survive 7 HPR**

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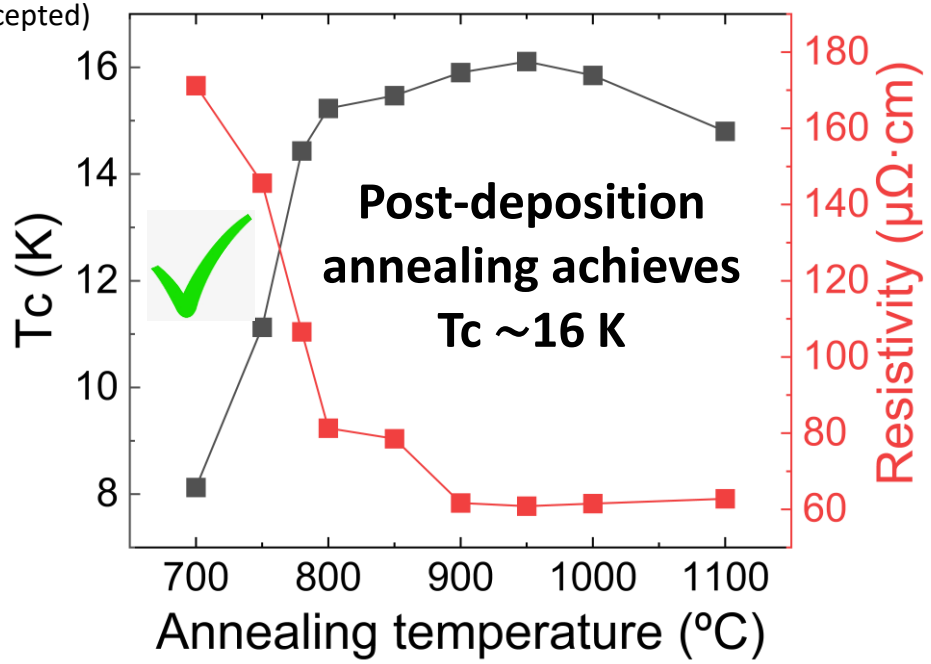


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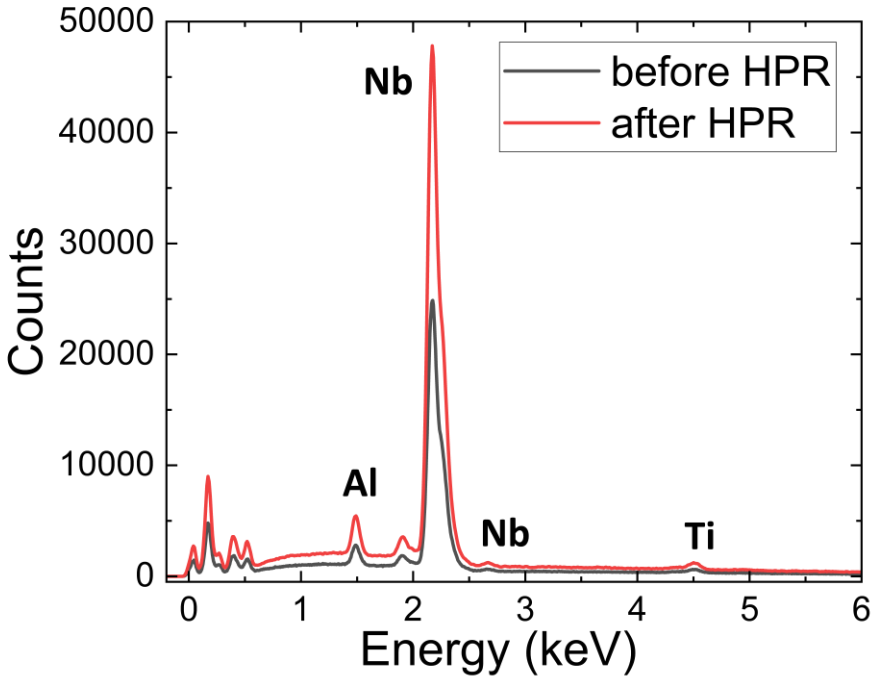


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- Field emission from planar films threshold voltage of:

**Annealed: 281 MV/m**
**As-deposited: 95 MV/m**

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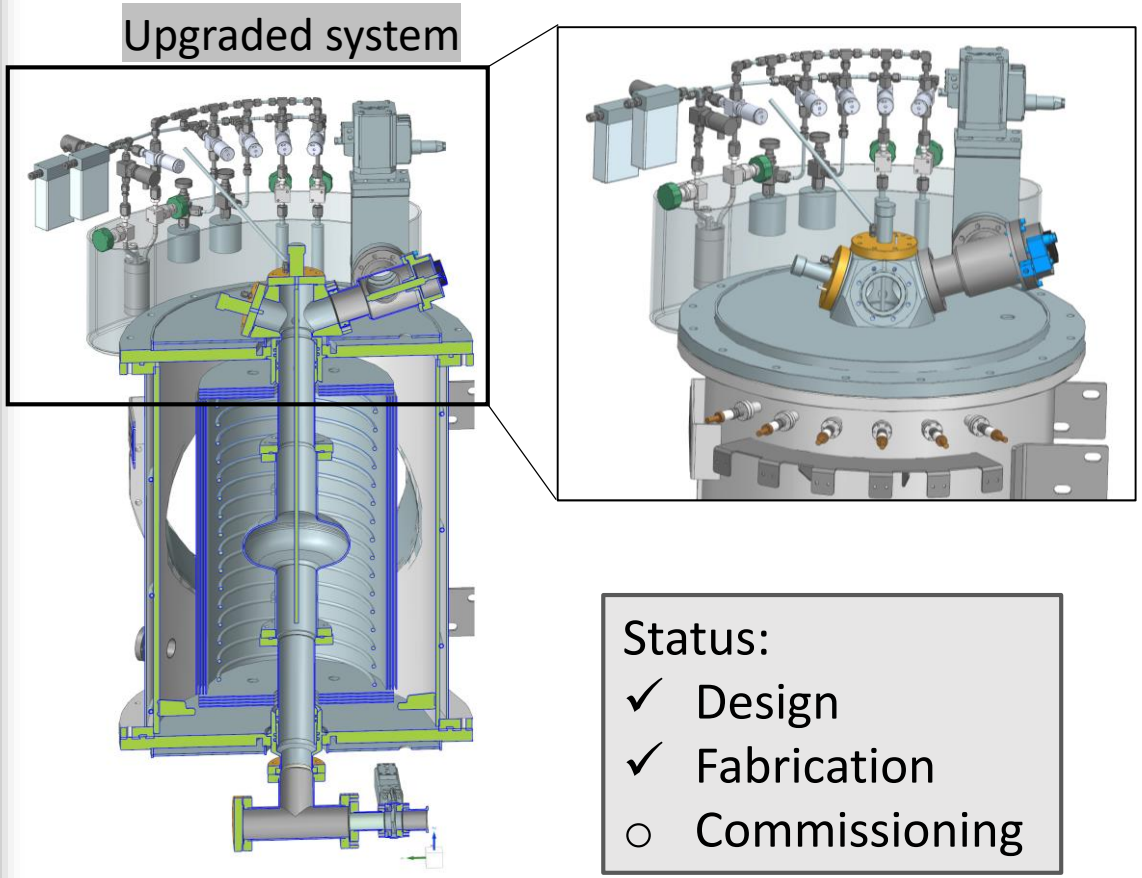
# PEALD AlN-NbTiN cavity coating – starting next year


**EXTEND SINGLE-CELL FURNACE TO PEALD-SINGLE-CELL COATING SYSTEM**

Upgraded system



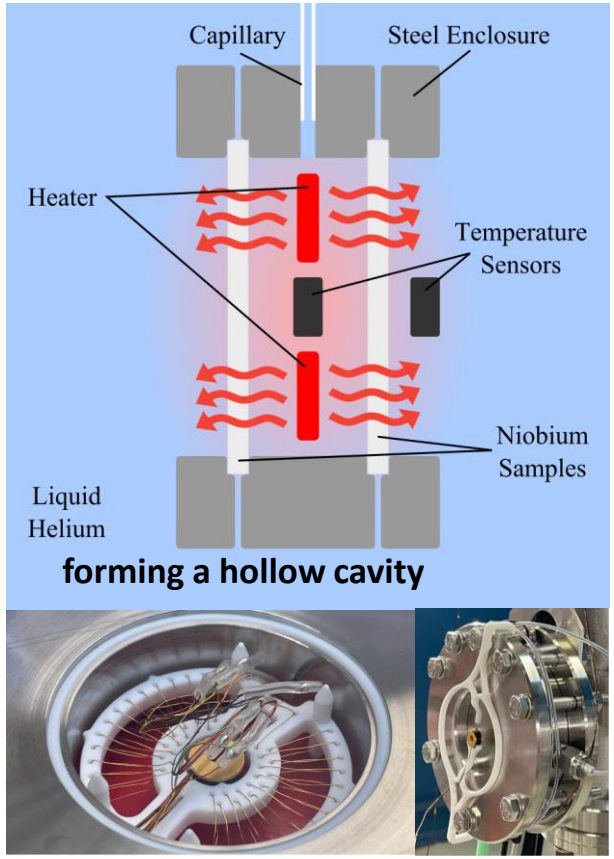
Status:
- ✓ Design
- ✓ Fabrication
- ○ Commissioning

**High versatility** in one system:

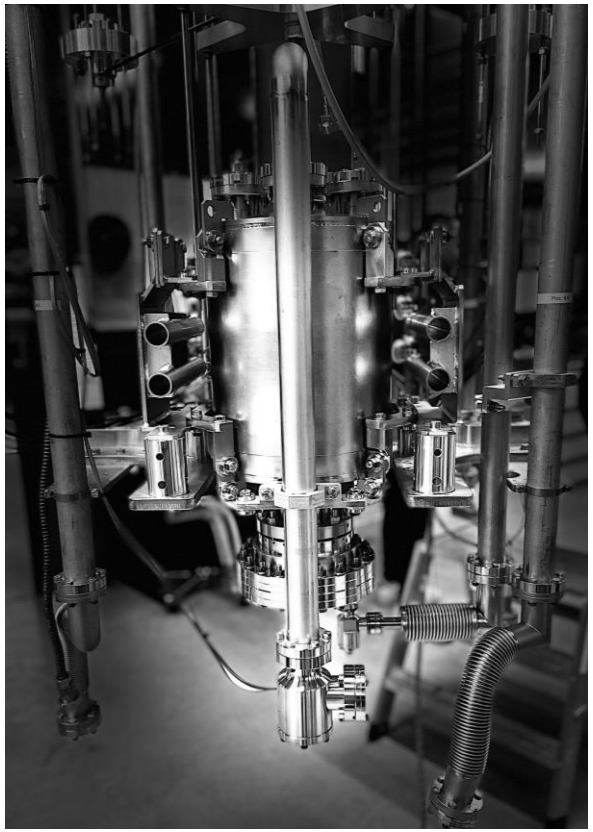
- PEALD and thermal ALD
- Capable depositing:
  - NbTiN / NbN
  - AlN
  - $Al_2O_3$
- In-situ annealing
  - dissolve oxide layers before coating
  - after coating

# Related activities ongoing

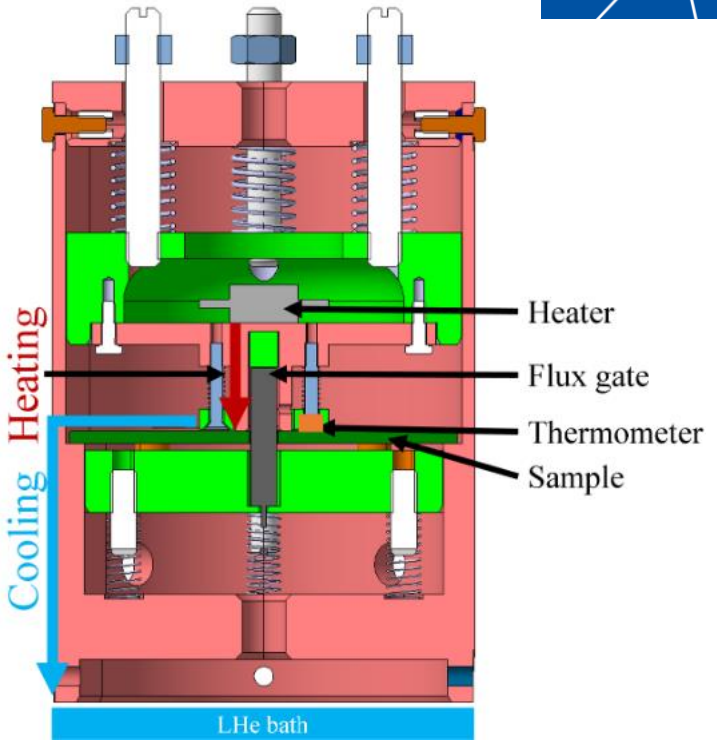
- Thermal conductivity studies at UHH/DESY




- Commissioning of the UHH Quadrupole Resonator (QPR) at DESY



- Flux expulsion studies at CERN



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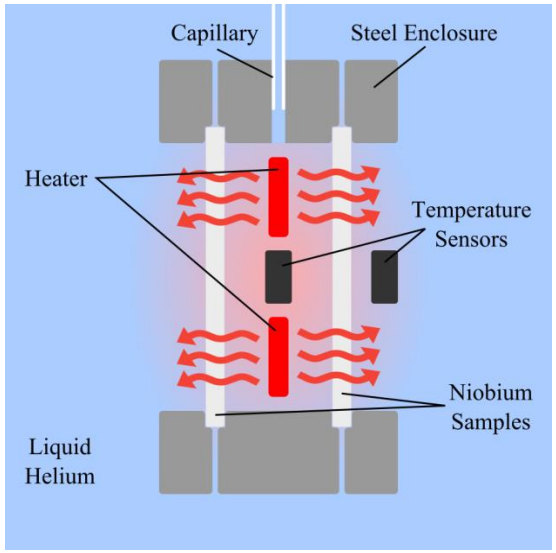
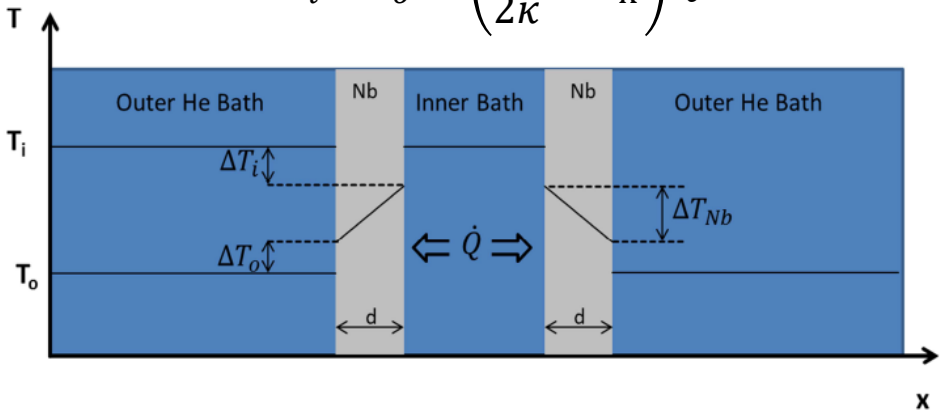



$$\Delta T = T_i - T_o = \left(\frac{d}{2\kappa} + R_K\right)\dot{Q}$$



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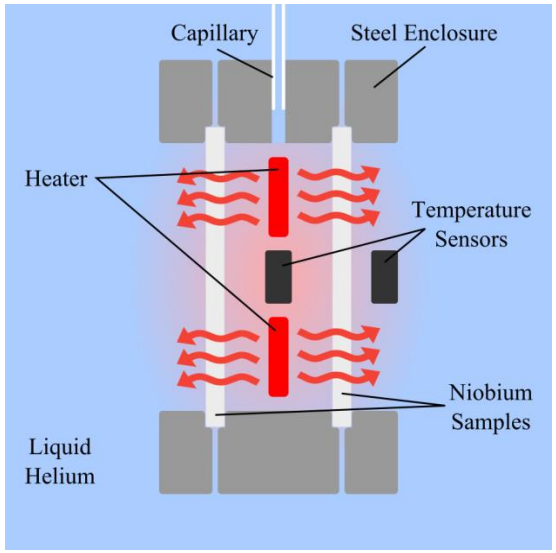


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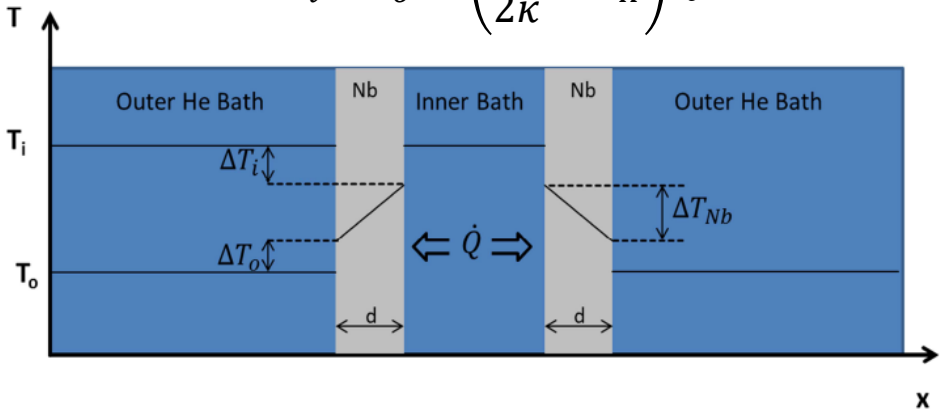


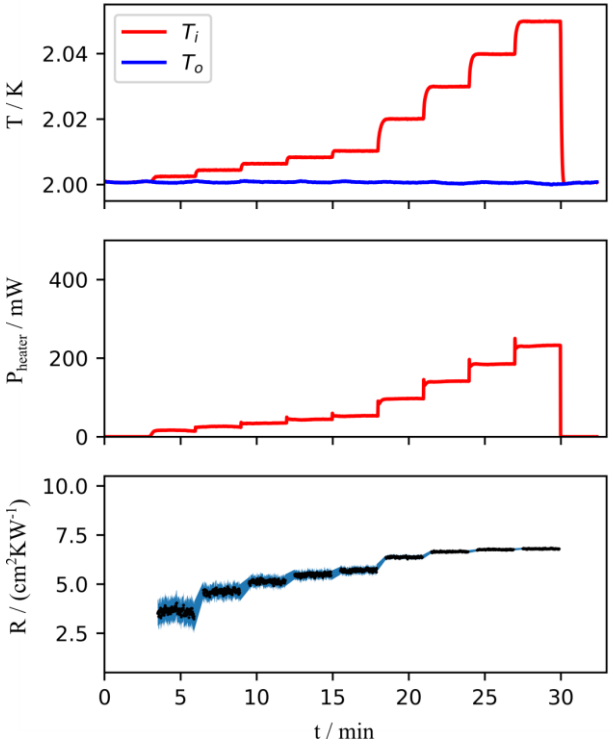

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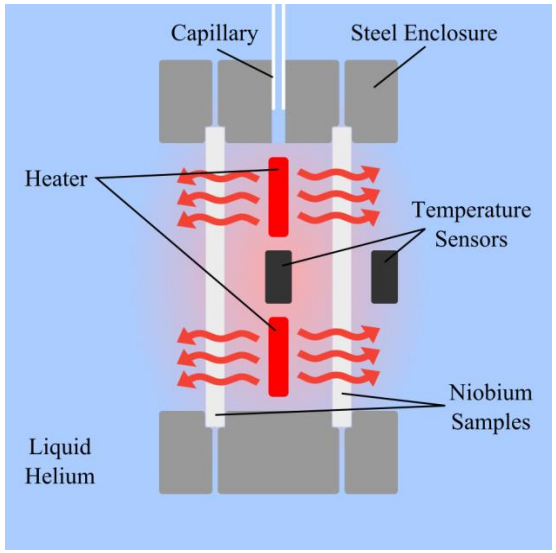


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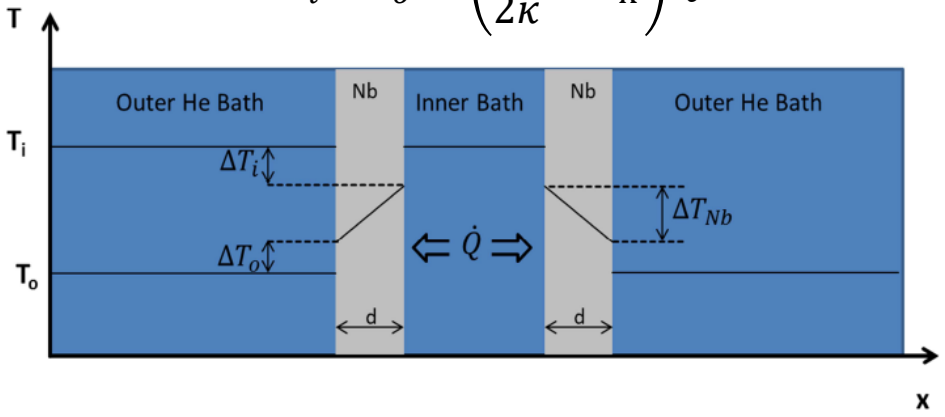


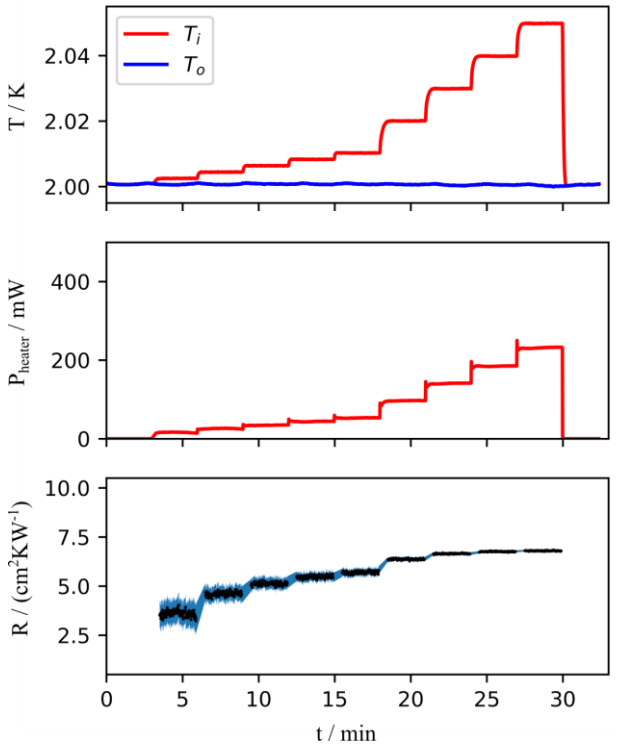


| Cool Down | Sample Pair | Treatment | $K_{samples}$ ($Wcm^{-2}K^{-1}$) | $3\sigma$ |
|---|---|---|---|---|
| 1 | 1 | as-fabricated | 0.307 | 0.046 |
| 2 | 1 | BCP 1 | 0.404 | 0.120 |
| 3 | 3 | as-fabricated | 0.332 | 0.031 |
| 4 | 2 | BCP 1 + outgassing 1 | 0.167 | 0.016 |
| 5 | 3 | BCP 2 | 0.280 | 0.030 |
| 6 | 4 | BCP 2 + outgassing 2 | 0.200 | 0.019 |
| 7 | 3 | BCP 2 + outgassing 2 + SIS | 0.141 | 0.013 |

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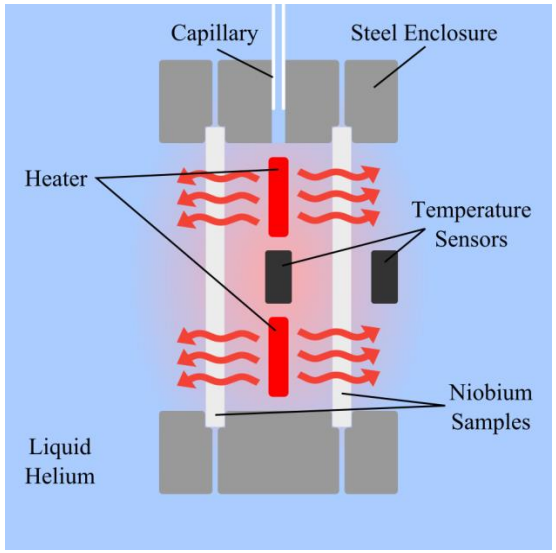


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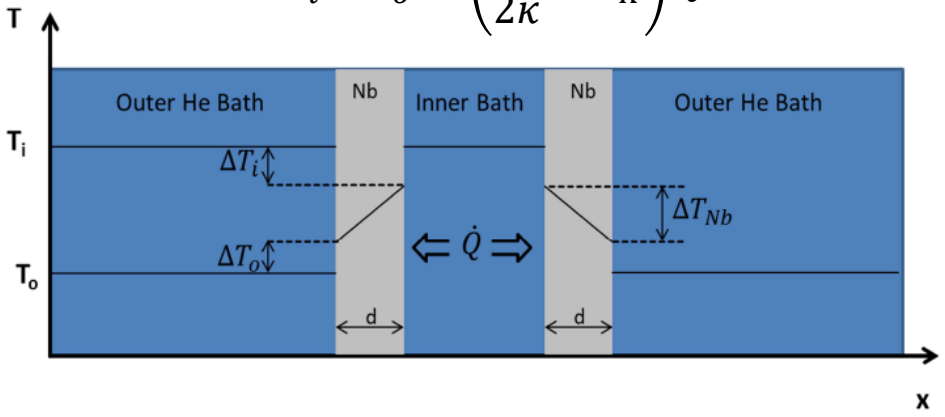


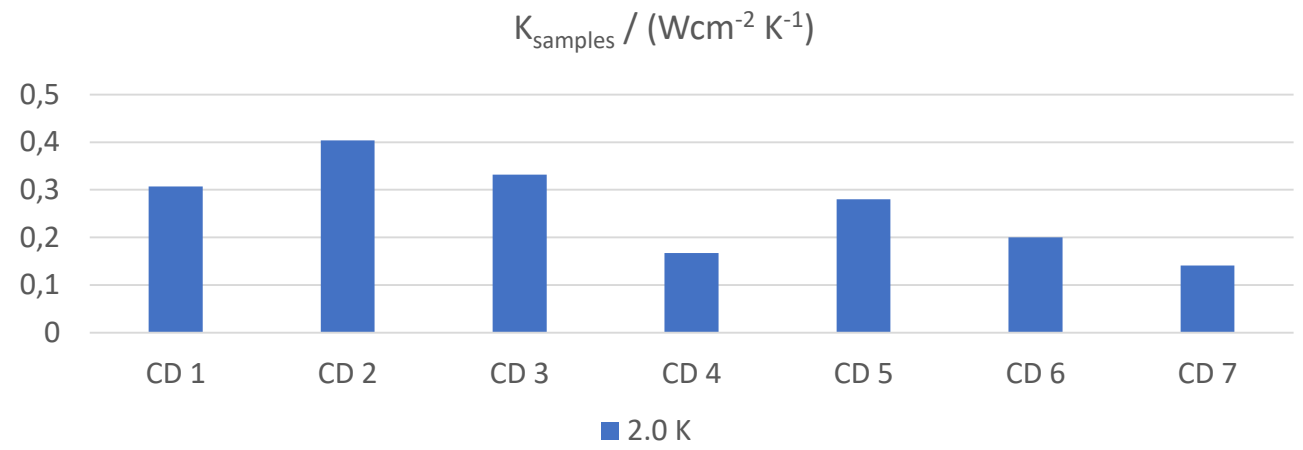


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# Take home messages

- ✓ Achieve coated cavities by thermal ALD and sustain high accelerating gradients without any performance deterioration
- ✓ SIS multilayers by PEALD and post-deposition annealing have been optimized on planar substrates – move on to cavities
- ✓ Continue material R&D and investigate potential showstoppers

**Thanks to:**
**SRF R&D group DESY/UHH**: Wolfgang Hillert, Hans Weise, Detlef Reschke, Marc Wenskat, Getnet Kacha Deyu, Cornelius Martens, Lea Steder, Rezvan Ghanbari, Lea Preece, Cem Saribal, Nicolay Krupka, Christopher Bate, Ricardo Monroy-Villa, Jonas Wolf, Mateusz Wiencek, and many more. **ALD group UHH (CHyN):** Robert Blick, Robert Zierold, Jun Peng, Carina Hedrich, Stefanie Haugg, Kristian Deneke, Malte Siegmung and more. **Collaborators**: Dirk Lützenkirchen-Hecht (U. Wuppertal), Frederic Braun (U. Wuppertal), Alick Macpherson (CERN), Daniel Turner (CERN), Tobias Junginger (U. Victoria) and more. **Organizing Committee**

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**Thank you for your attention**

Please, feel free to contact via: igonzale@physnet.uni-hamburg.de

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