HZB BESSY II Light Source

MEASUREMENTS OF BREMSSTRAHLUNG BY FIELD EMISSION FROM THE BESSY HOM CAVITIES

…and other news from HZB

RadSynch23, Grenoble
Holger Huck, 01.06.2023

BESSY II
SEAlab

HZB: Facts and figures

Lise Meitner Campus

Locations

Wannsee

Adlershof

Wilhelm Conrad Röntgen Campus

~1250 employees

~600 researchers
incl. 100 PhD students
~30 trainees
~10 young investigator groups

~2700 visits p.a. from guest researchers

~30 countries

Funding

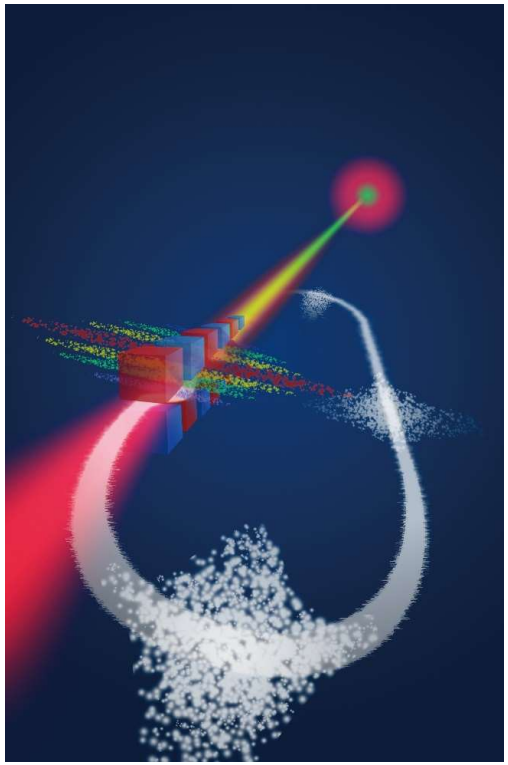
10% State of Berlin
90% federal government

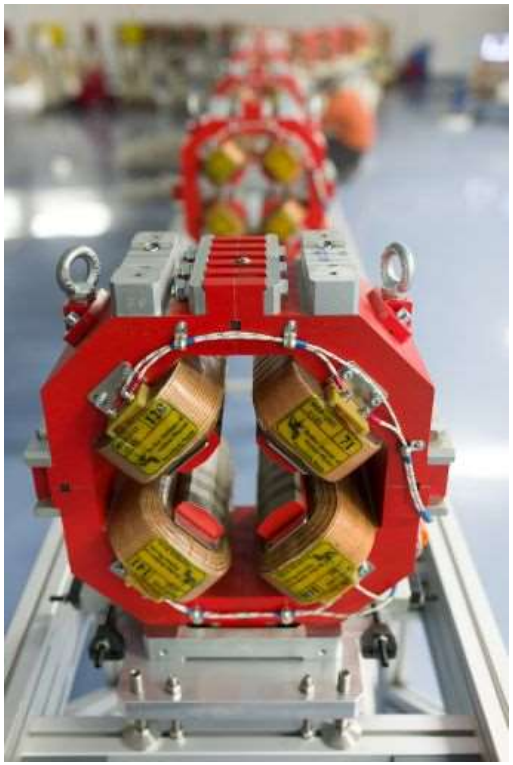
Budget

approx. €190 million p.a.

Accelerators

- Operation and development of
  - **BESSY II**
  - **Metrology Light Source - MLS** (PTB)
  - an accelerator for **eye tumour therapy**
- Design of successors **BESSY III** and **MLS II**
- Innovative operation schemes
- Sustainable accelerator concepts
- SRF technology (e.g. VSR-Demo)
- Advanced accelerator test infrastructures for industrial components (**SEALab, bERLinPro**)

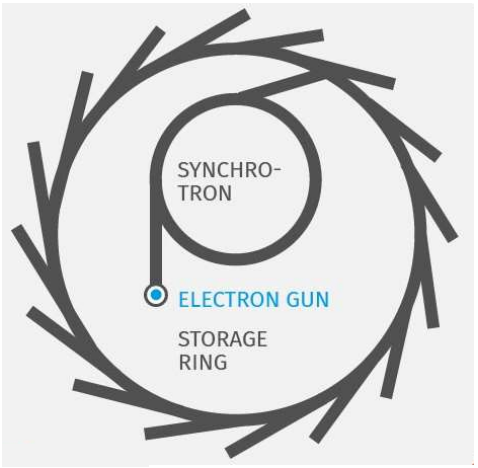




BESSY II:
Brilliant light for science

- Electron storage ring with 240 m circumference (1.7 GeV, 300 mA)
- Brilliant X-ray radiation for research; focus on **soft X-rays**
- **38 beamlines** in user operation
- **~ 2700 user visits** p.a. from ~30 countries
- Primary source standard for PTB‘s metrology

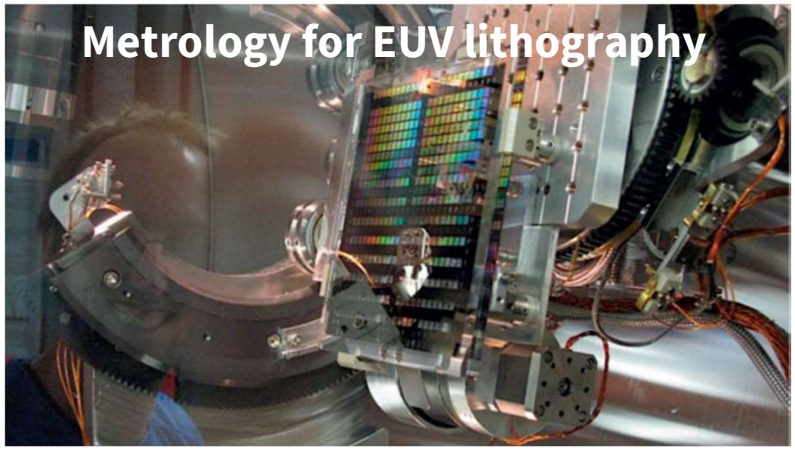
Scheme synchrotron/storage ring



HZB BESSY II Light Source

Highest accuracy: PTB @ BESSY II

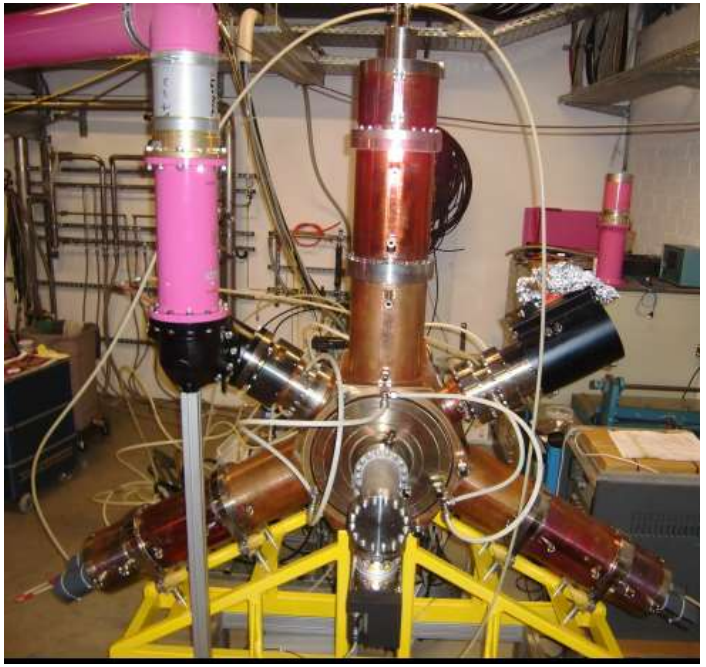
- PTB uses BESSY II and MLS (Metrology Light Source) for **metrology with synchrotron radiation**
- For industry and materials science applications
- Examples: EUV lithography and space instruments
- MLS: 650 MeV, 200 mA



BESSY HOM Cavity

BESSY HOM CAVITY

- Developed by a collaboration 15-20 years ago
- Early tests at MLS [1] and DELTA [2] (Dortmund University)
- Installed at BESSY II 2013/2015 [3]
- Also in operation at ALBA, planned for DIAMOND



- **500 MHz, NC, HOM damped single cell cavity**
- **3.4 MΩ shunt impedance**
- **80 kW / 738 kV**

[1] F. Marheuser, E. Weihreter, Proc. EPAC2004, Lucerne, pp. 979-981, 2004
[2] T. Weis et al., Proc. RuPAC2006, Novosibirsk, pp. 138-140, 2006
[3] W. Anders et al., Proc. IPAC2017, Copenhagen, THPIK013, 2017

EARLY „INCIDENT“

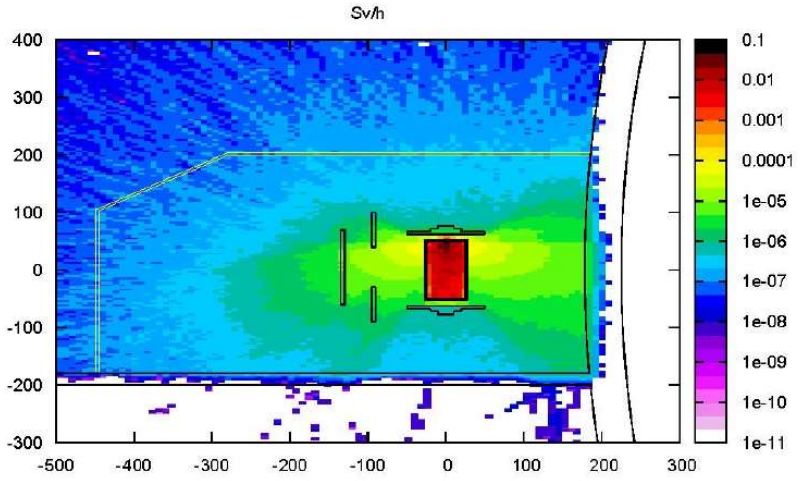
- During installation several years ago, cavities were accidently operated at high power (~40 kW) with people working in the tunnel
- Alarm from ambient dosimetry: 5 µSv/h at 3 m distance
- Fortunately no personal doses detected (<0.1 mSv)

- Consequently, a separate exclusion area was defined for future RF tests in the SR tunnel

- **5 µSv/h @3m (transverse)**
- **40 kW / 520 kV**

CAVITY TEST STAND

- Conditioning of spare cavities
- Fenced-in, exclusion area on the roof of SR tunnel
- Several „mobile“ lead walls
- Shielding design based on FLUKA simulations and the previous 40 kW measurements



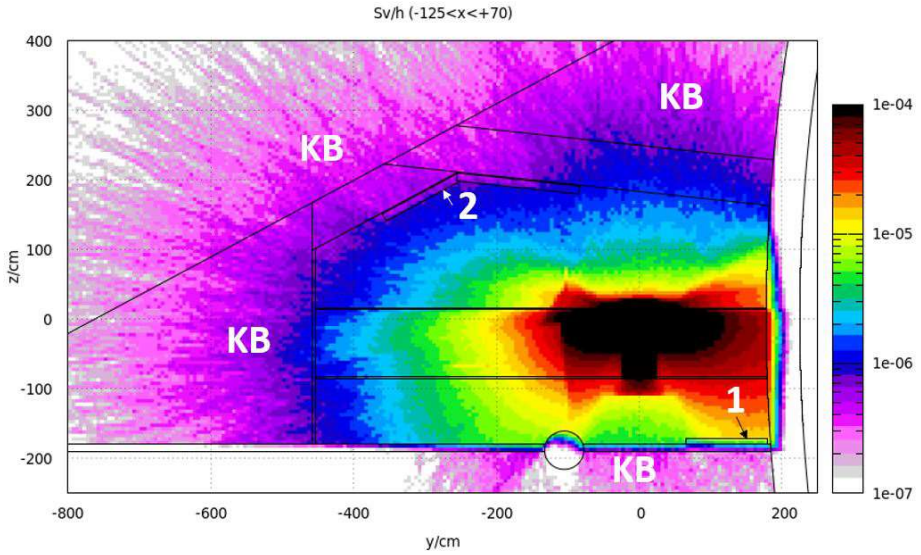
- **< 0.5 µSv/h outside fence**
- **40 kW / 520 kV**

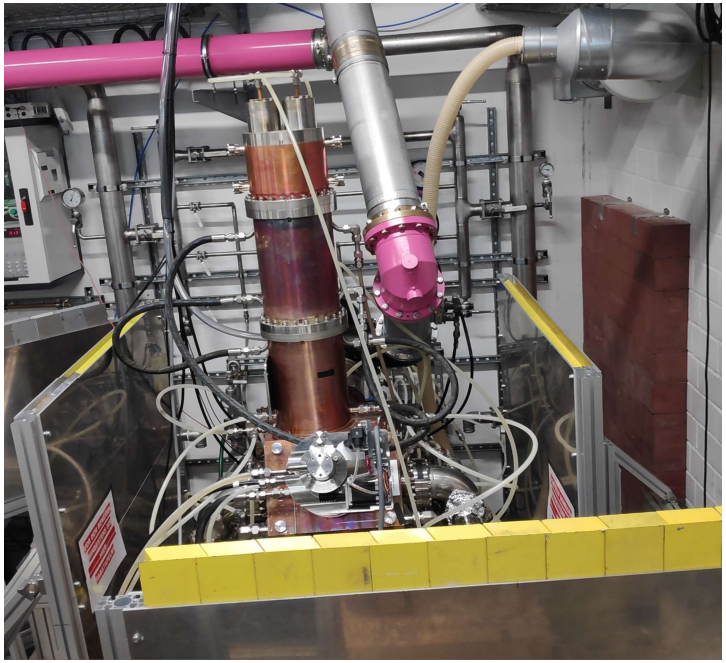
FIELD EMISSION

- In the vicinity of local impurities (dirt, scratches), electrons can escape the cavity walls (local spikes in field strength)
- Accelerated electrons hit opposite wall and produce X-rays
- Hard to predict, and theory not fully understood
- Much worse for super-conducting cavities (higher gradients, risk of quench)
- @HZB, highest dose rate ever measured was 5 Sv/h from a TESLA 9-cell SRF cavity

TEST STAND UPGRADE (01.06.2021)

- New 80 kW SSA, new LLRF
- Upgrade of shielding necessary
- First approach: simulation with same loss current, but higher voltage, resulting in 2-3x dose rate (vs. 40 kW)

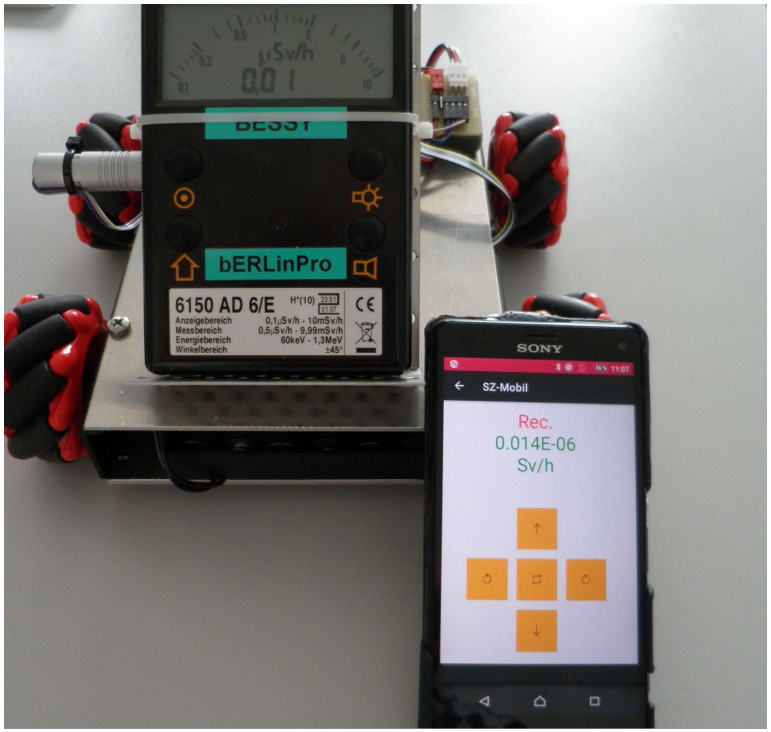




- **80 kW / 738 kV**
- **More lead walls**
- **Additional heavy concrete**

MEASUREMENT EQUIPMENT

- Mobile ionization chamber automess 6150 AD [1]
- Data transfer by wifi/bluetooth (DIY solution)
- Logging: raspberry pi or phone
- Remote controlled car/robot available



- Outside fence: Berthold UMo LB 123 (50 nSv/h – 100 mSv/h)

- **0.5 µSv/h – 10 mSv/h**
- **60 keV – 1.3 MeV**
- **Can be „officially“ calibrated**

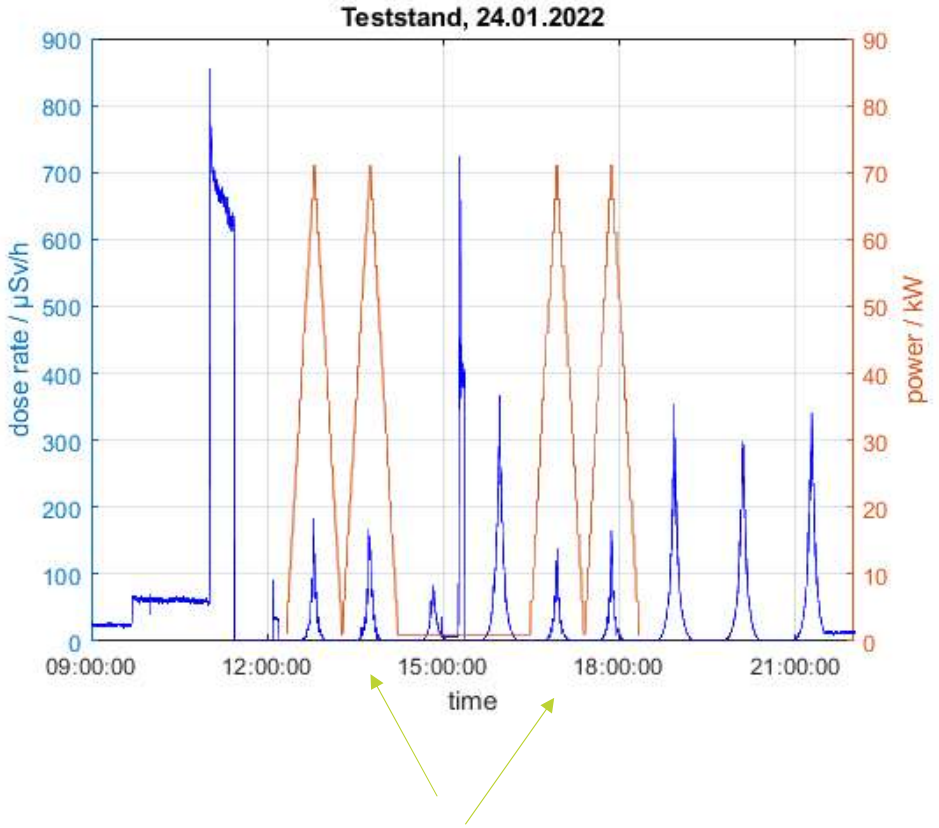
[1] www.automess.de

MEASUREMENTS

- Some difficulties with coupling and cooling
- Eventually reached up to 71 kW in cavity (695 kV)
- Outside fence: up to 9 µSv/h (20 µSv/h @3m height)

- …and up to **900 µSv/h** directly below cavity (125 cm distance to axis)

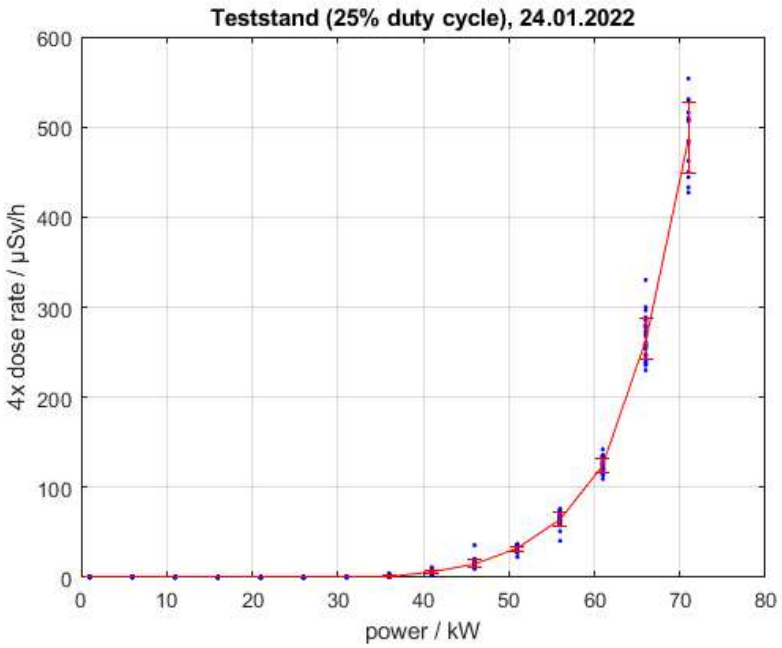
- Later tests were mostly done pulsed (better cooling and reduced radiation)

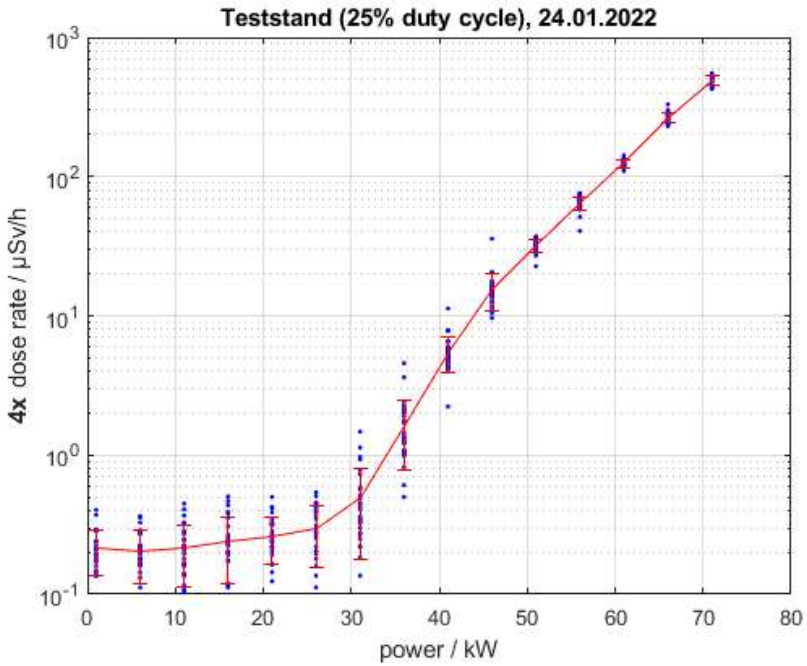


RF on/off for 250/750 ms

MEASUREMENTS

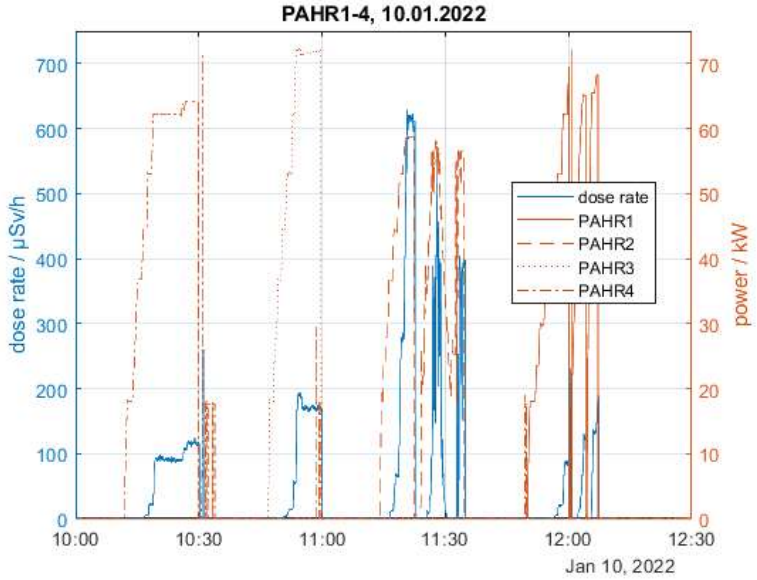
- Lower dose rates after initial conditioning and in pulsed mode, but still several 100 µSv/h
- Roughly exponential rise with power, starting at ~30 kW





INSIDE THE SR TUNNEL

- Short time slot for measurements
- Limited by vacuum, cavities not fully conditioned
- One problematic cavity (#2)



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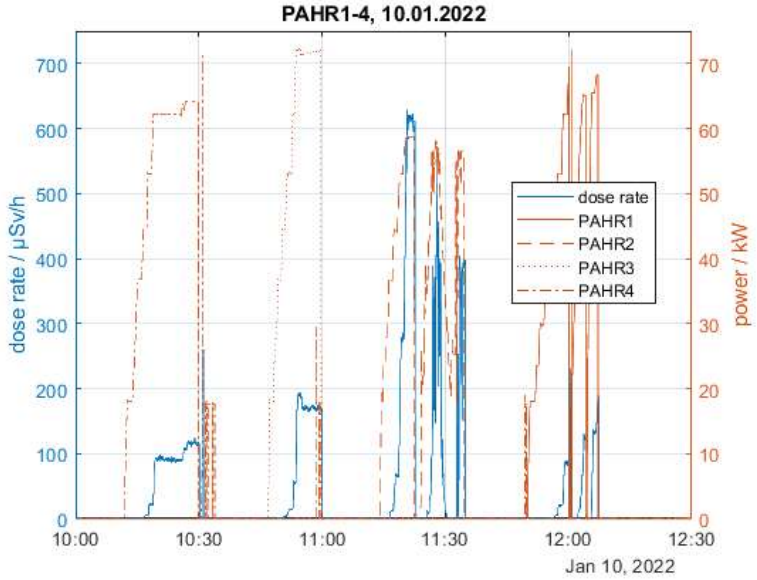
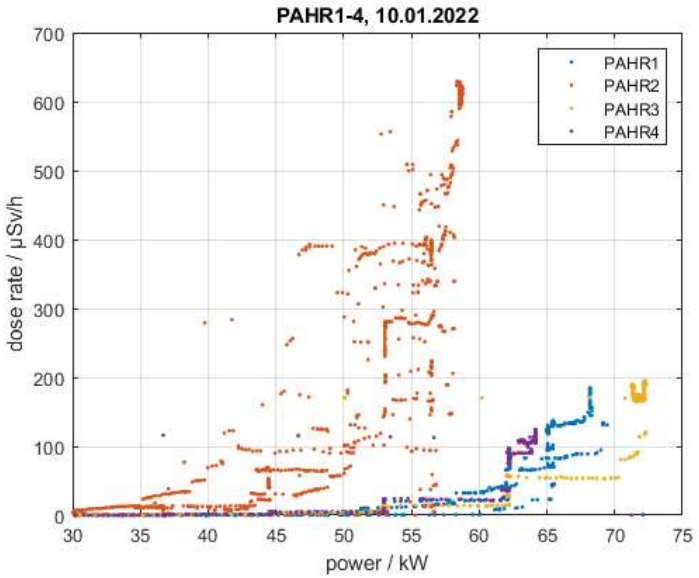
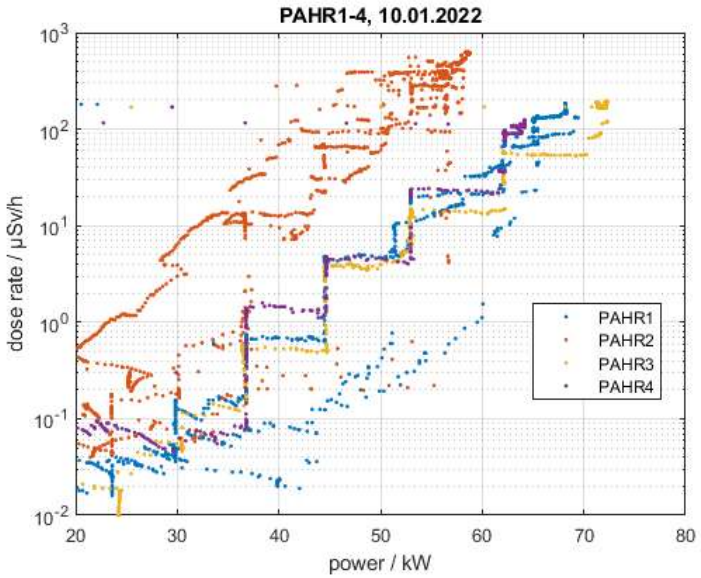






RESULTS…

- Up to 1 mSv/h @1m by field emission from a normal conducting cavity (500 MHz, 75 kW, 700 kV)
- Exponential rise of FE with power, starting from a certain threshold (consistent with SRF case)
- Threshold can vary, depending on conditioning, surface quality, vacuum, temperature…
- Another cavity was tested up to 50 kW (similar dose rates, worse cooling issues)

…AND PLANS

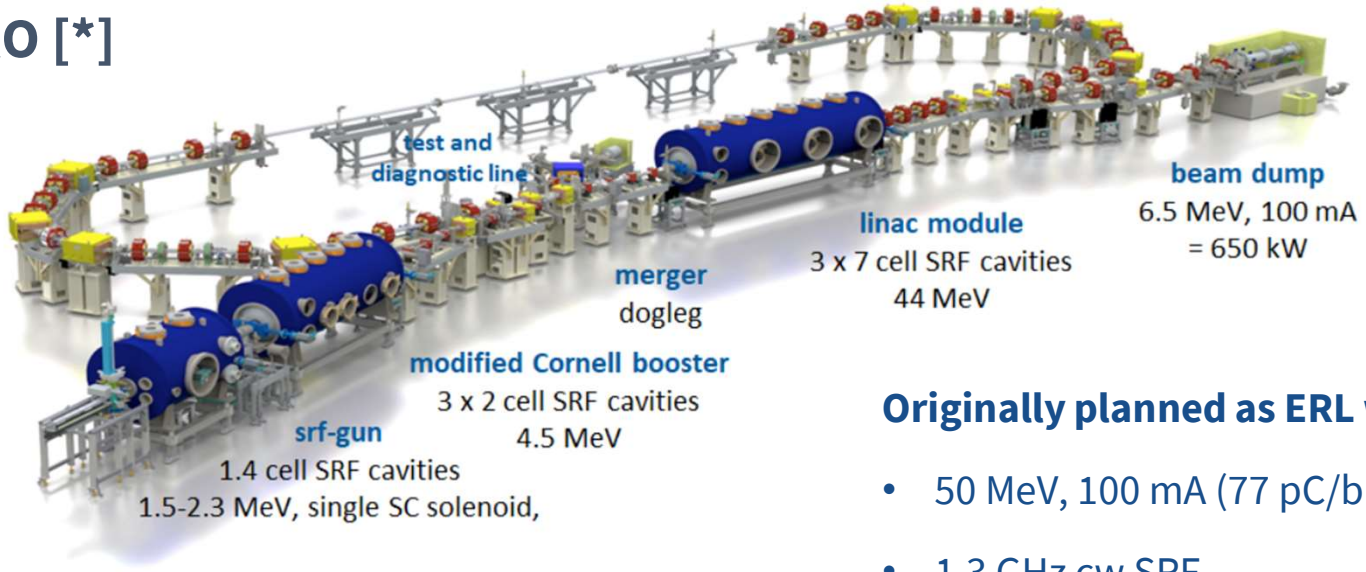
- **Test stand dormant since ~1y, due to LLRF issues and general work load on RF group**
- **Plans to measure 2 other cavities**
- **Additional shielding required**
- **Better cooling might help?**

…and other news from HZB

BERLINPRO AND SEALAB

- The „Berlin ERL Project“ officially ended 2020 with completion of the building, infrastructure and major warm systems
- Until today no e-beam in the bunker, due to major delays in many subprojects
- Activities continue under the name SEALAB (Superconducting RF Electron Accelerator Laboratory)

BERLINPRO [*]



Originally planned as ERL with:

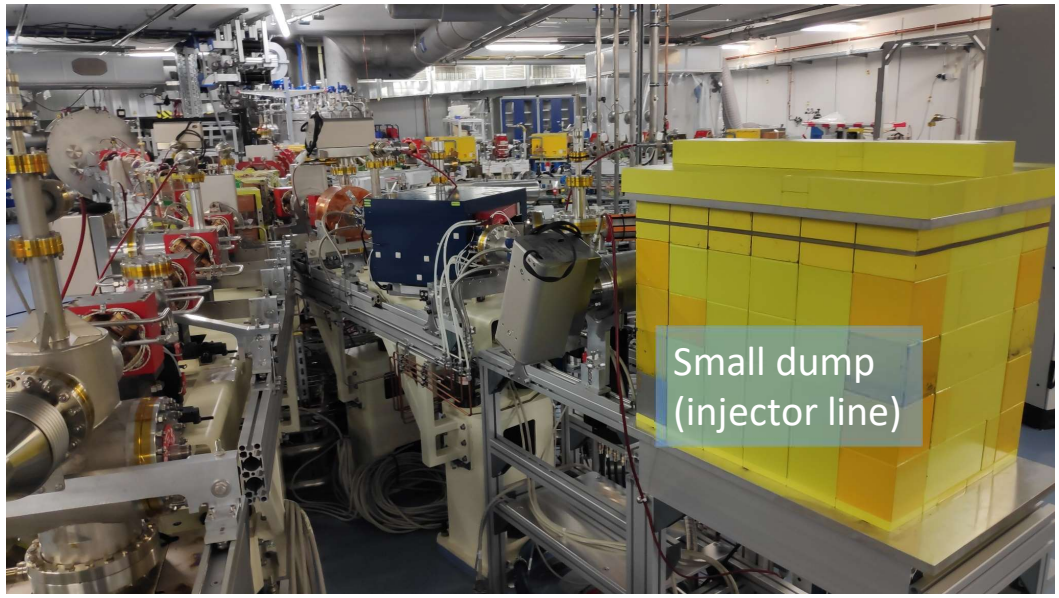
- 50 MeV, 100 mA (77 pC/bunch)
- 1.3 GHz cw SRF
- 1 mm mrad normalized emittance
- 100 fs – 2 ps bunch length

[*] M. Abo-Bakr et al., “Status Report of the Berlin Energy Recovery Linac Project BERLinPro”, Proc. IPAC’18, Vancouver, Canada, Apr.-May 2018, pp. 4127–4130

RADIATION PROTECTION [1-3]

- All systems completed:
  - Personnel safety interlock (PSI)
  - Ambient dosimetry
  - Air activation/emission monitoring
  - Machine activation measurement
  - Leakage water collection
  - Bulk & dump shielding

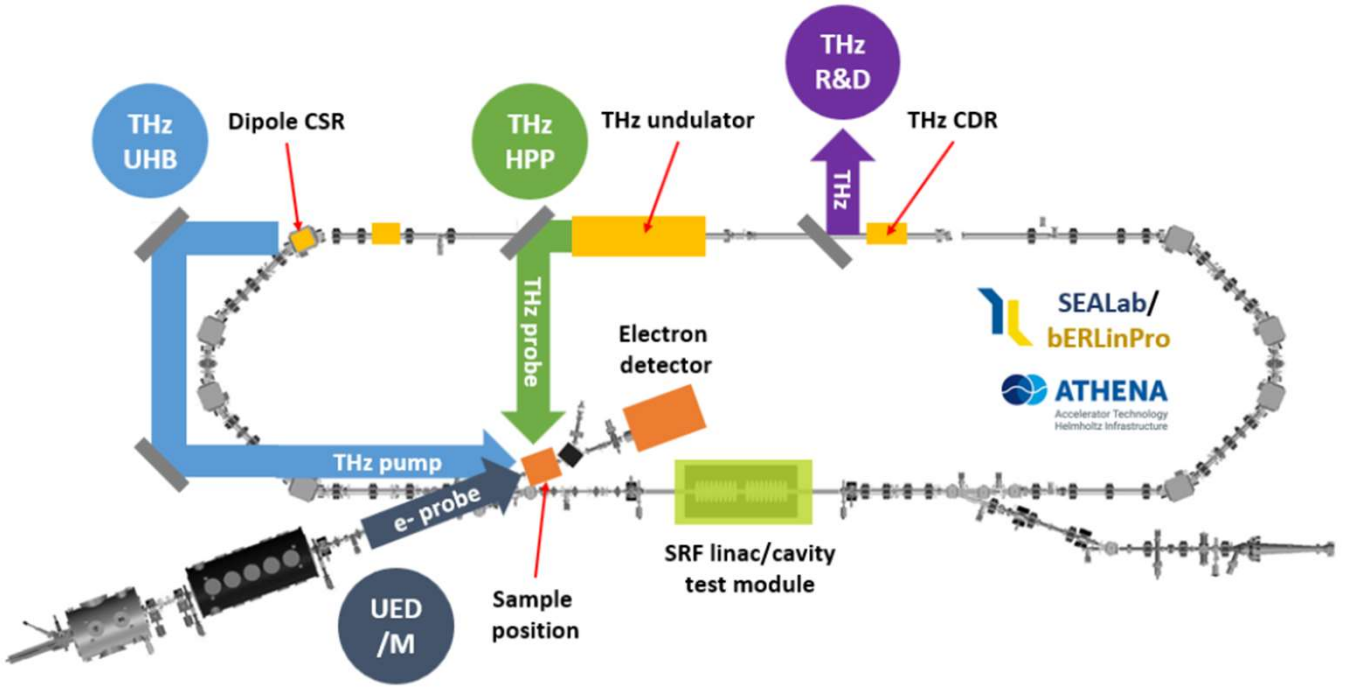

Radiation protection gate (77 tons)


Small dump (injector line)

[1] L. Pichl et al., “Radiation Protection Instrumentation of bERLinPro”, RadSynch19, Lund, 2019
[2] K. Ott, Y. Bergmann, “Radiation Protection Issues of bERLinPro”, RadSynch15, Hamburg, 2015
[3] K. Ott, M. Helmecke, “The Shielding Design of bERLinPro”, Proc. IPAC2011, San Sebastian, 2011

THE SEALAB VISION [*]

- R&D outside a rigid project structure
- Flexible test facility for CW SRF
- UED as first application of the injector



[*] A. Neumann et al., ”bERLinPro BECOMES SEALab: STATUS AND PERSPECTIVE OF THE ENERGY RECOVERY LINAC AT HZB”, Proc. IPAC2022, Bangkok, TUPOPT048, 2022

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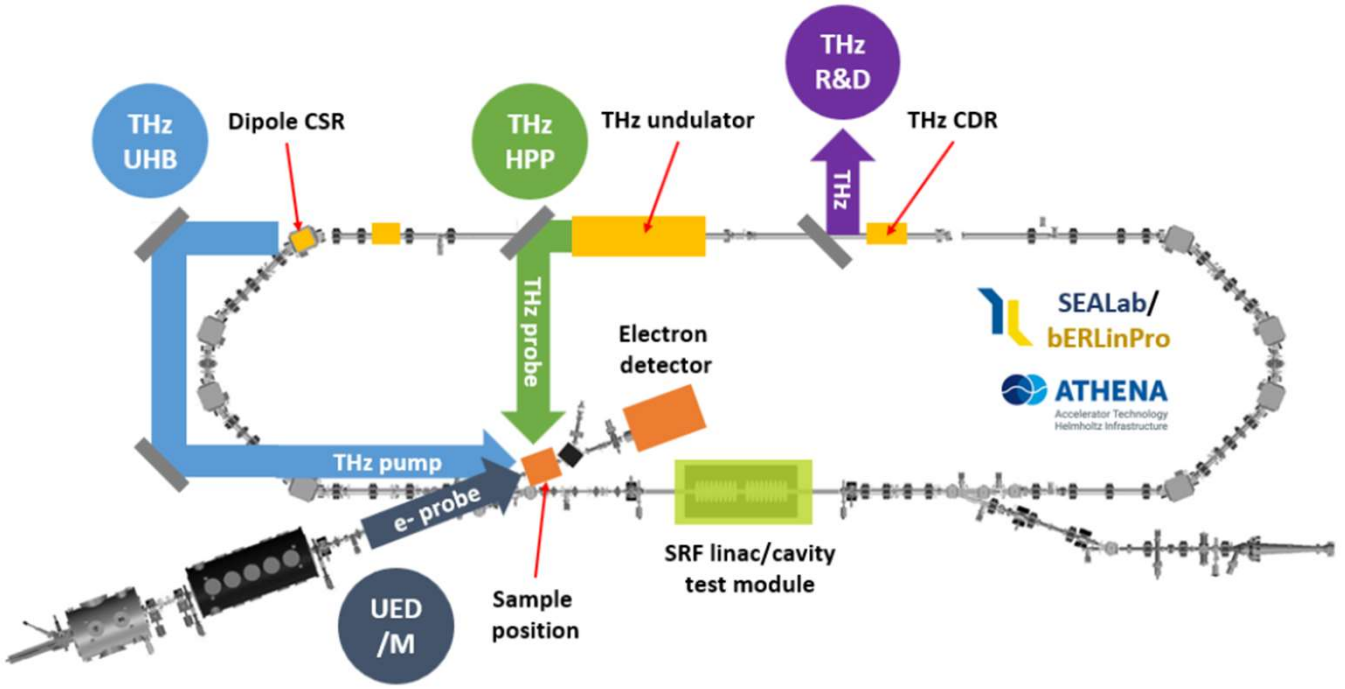


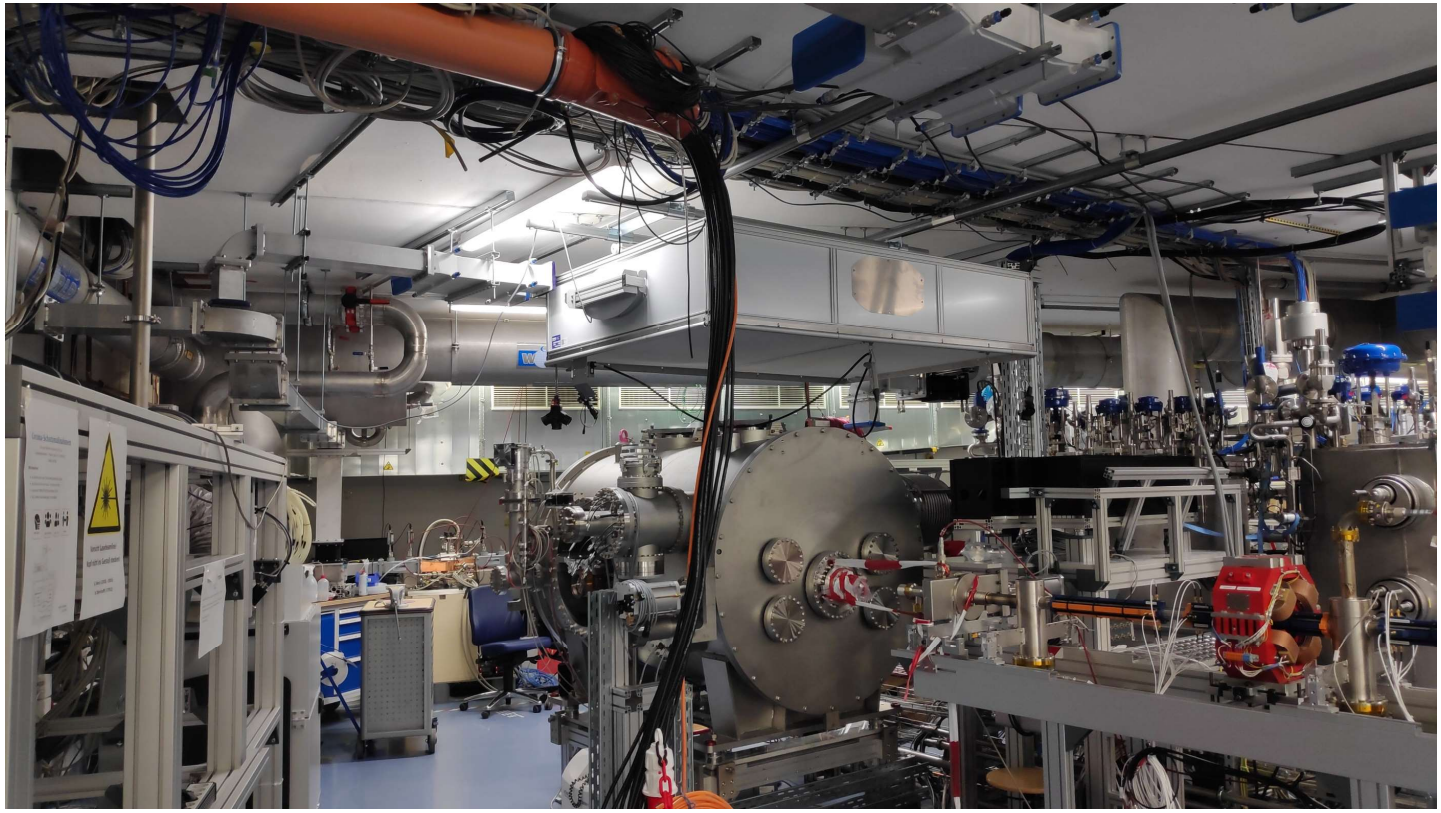
- …actual plans exist for gun, booster and UED
- First gun RF tests expected this summer, photoelectrons several months later

Parameters for injector/UED:

- E < 10 MeV (no activation)
- I < 10 mA
- 0.05 – 400 pC bunch charge

[*] A. Neumann et al., ”bERLinPro BECOMES SEALab: STATUS AND PERSPECTIVE OF THE ENERGY RECOVERY LINAC AT HZB”, Proc. IPAC2022, Bangkok, TUPOPT048, 2022

SEALAB STATUS

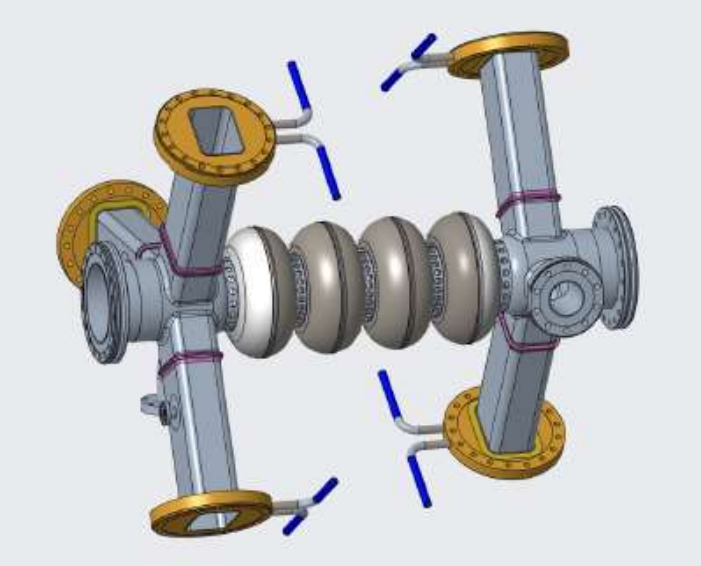


- Cavity & module in place
- Final RF connections TBD
- „1st meter“ TBD

- First gun RF tests expected this summer, photoelectrons several months later

LARGE VERTICAL TEST STAND (LVTS)

- Testing of SRF cavities w/o module
- Large, flexible cryo tank for different cavity types (but high He costs)
- 5 m deep bunker for 5 Sv/h
- Operation started 2 weeks ago



VSR Demo project:

- 4 cell, 1.5 GHz cavity (cw SRF)
- To be tested in LVTS & SEAlab
- Maybe useable for BESSY II(?)
- Delays by RI

Many thanks to…

Yvonne Bergmann, Anne Bundels, Lutz Pichl (co-authors)

Klaus Ott (retired)

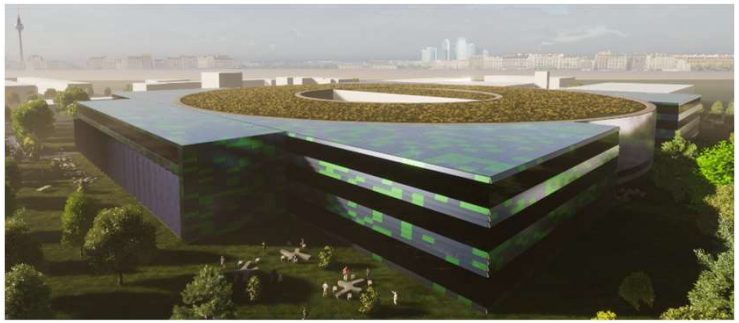
RF group

Thank you for your attention!

BESSY III – A materials discovery facility

BESSY III Mission: New materials and technologies for a sustainable future

Enabling advances in energy conversion and storage, catalysis, green IT, …



Multimodal *operando* and *in-situ* capabilities + Highest brilliance and coherence, nano-foci + Quantitative materials science (with PTB) + Materials Science Campus Berlin Adlershof + AI-guided autonomous research and FAIR data

→ The leading European facility for soft and tender X-rays

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