



H e l m h o l t z - I n s t i t u t
für Strahlen - und Kernphysik
Nussallee 14 - 16 53173 Bonn Germany



Positron Microbeams and their applications

Matz Haaks

- ▶ Down to the micron range: ideas and techniques
- ▶ The Bonn Positron Microprobe (BPM)
- ▶ Scanning Positron Microscopy (SPM):
Application to material science
- ▶ A commercial SPM?

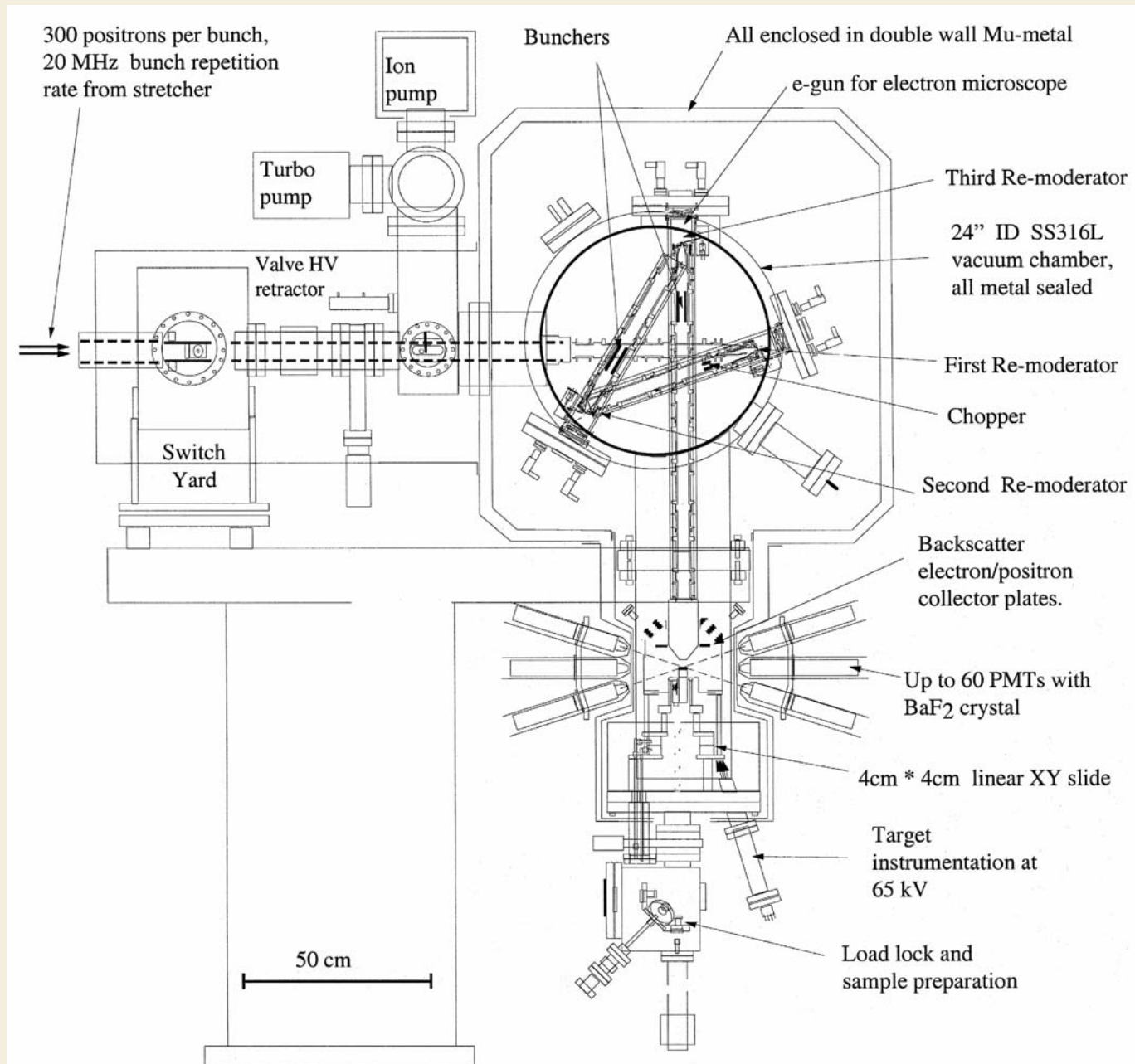
Building a positron microscope...

- ▶ Intense positron source (radioactive isotope, accelerator, reactor) with small phase space
- ▶ Mono-energetic positrons needed → efficient moderation.
solid noble gases (Ne), some pure metals (W, Mo)
- ▶ Remoderation: brightness enhancement
- ▶ Electrostatic acceleration
- ▶ Electromagnetic beam guiding
- ▶ Focusing into the micron range
- ▶ Scanning the beam (electromagnetic) or scanning the sample (motorized stage)

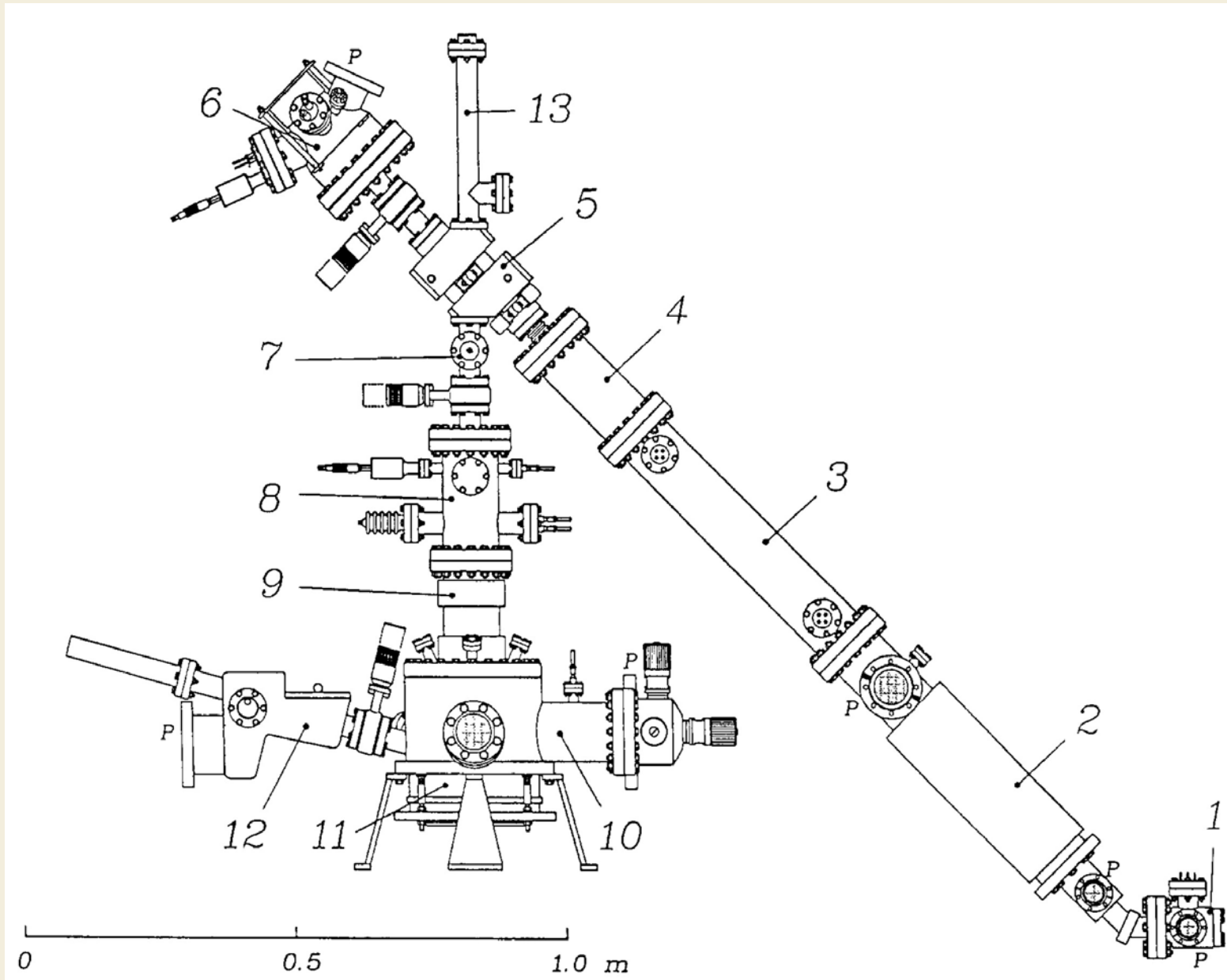
Physical resolution limits:

- ▶ Lateral: 0.2 - 2 μm (depending on positron energy and defect density)
- ▶ Depth: 0.1 - 5 μm (depending on positron energy)

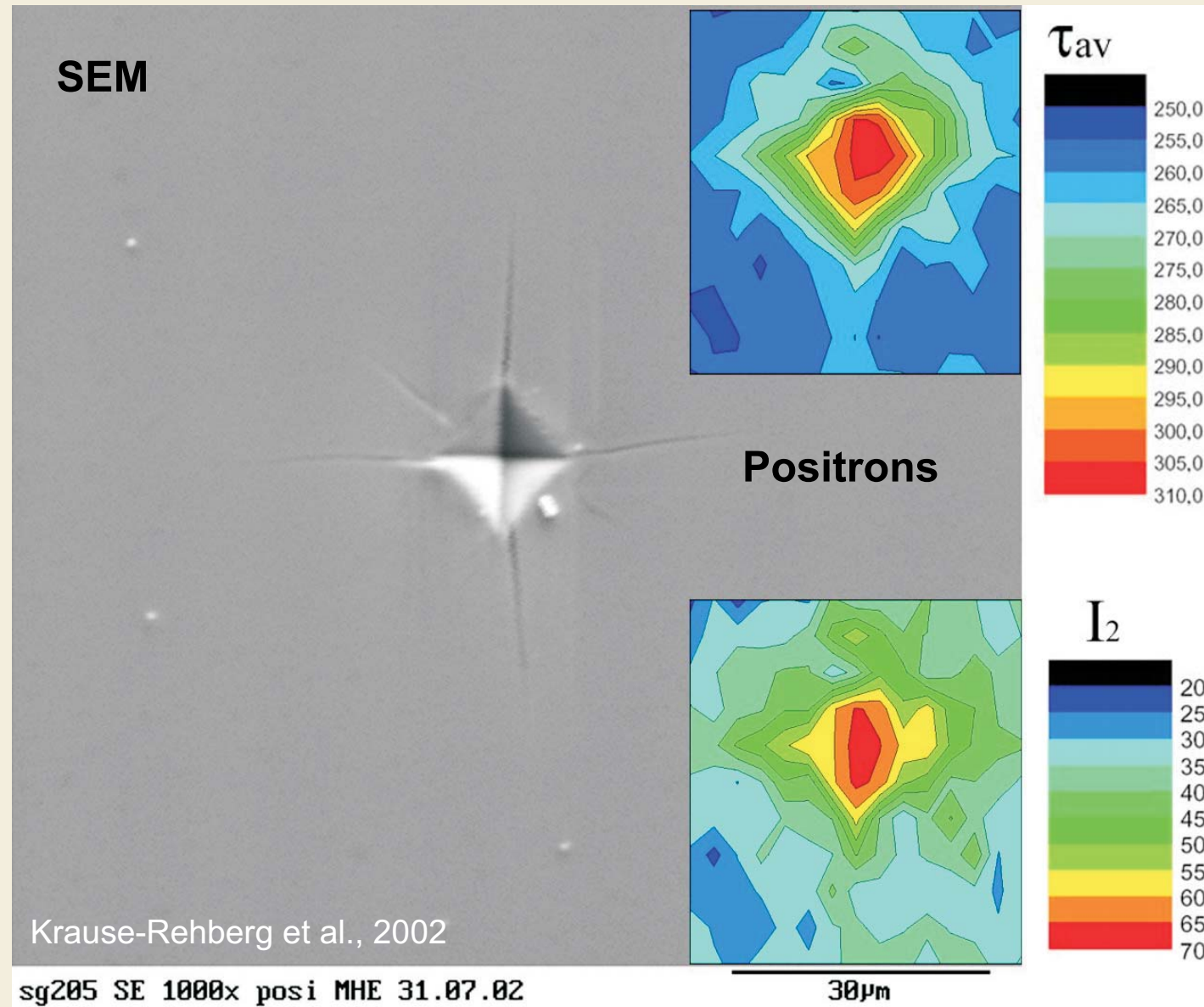
Positron microscope at the LLNL (e^+ -lifetime)



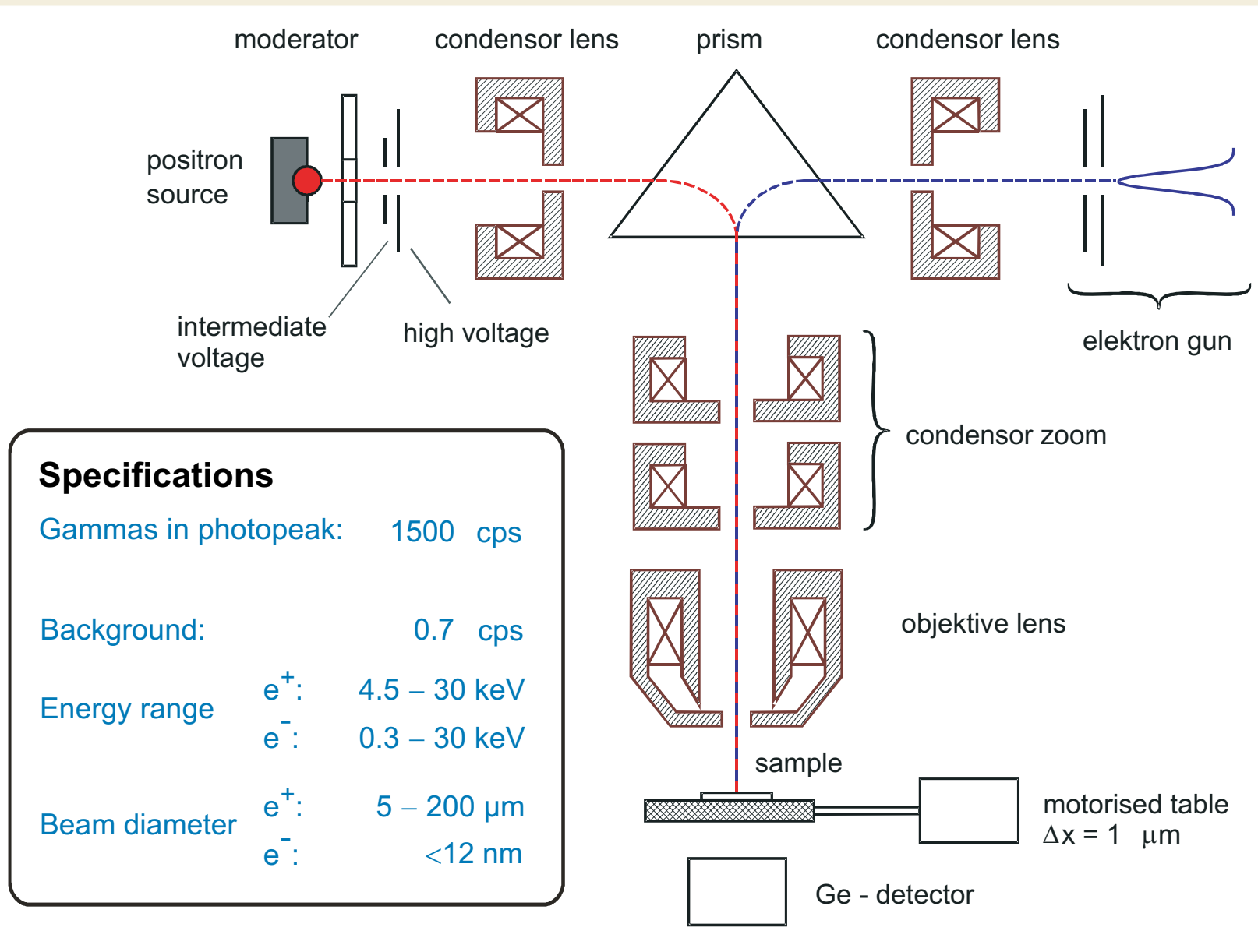
Positron microscope at the FRM II (e⁺-lifetime)



Microhardness indentation in GaAs



The Bonn Positron Microprobe (Doppler spectroscopy)



Specifications

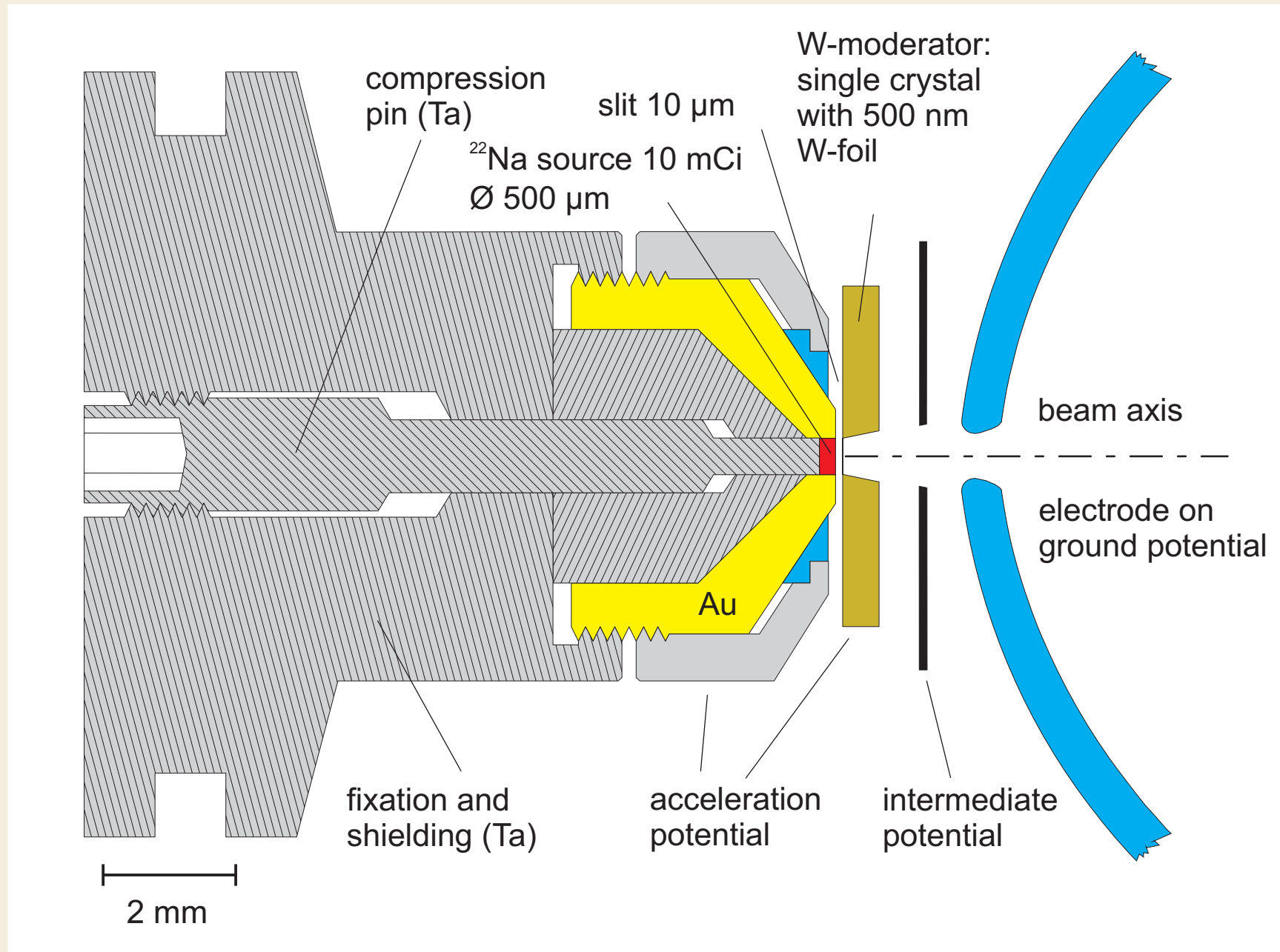
Gammas in photopeak: 1500 cps

Background: 0.7 cps

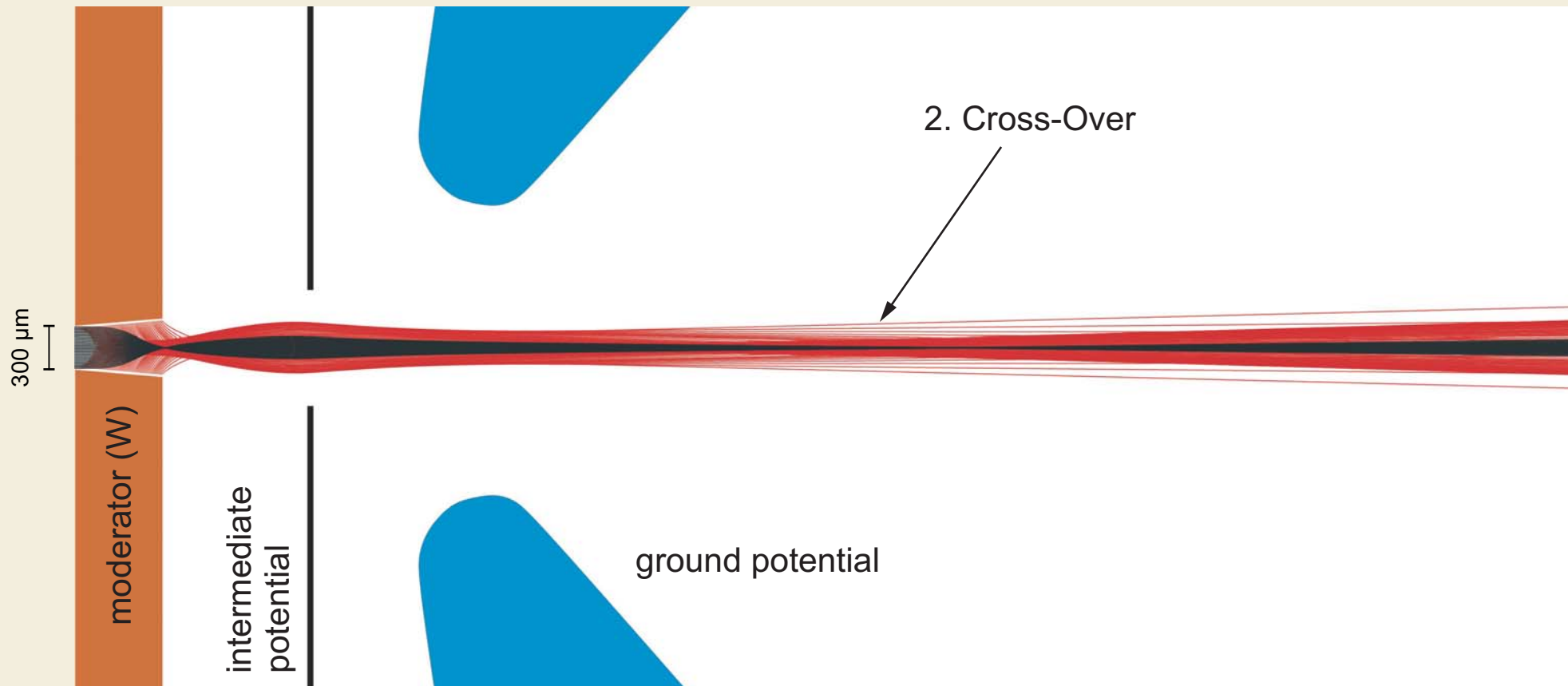
Energy range e^+ : 4.5 – 30 keV
 e^- : 0.3 – 30 keV

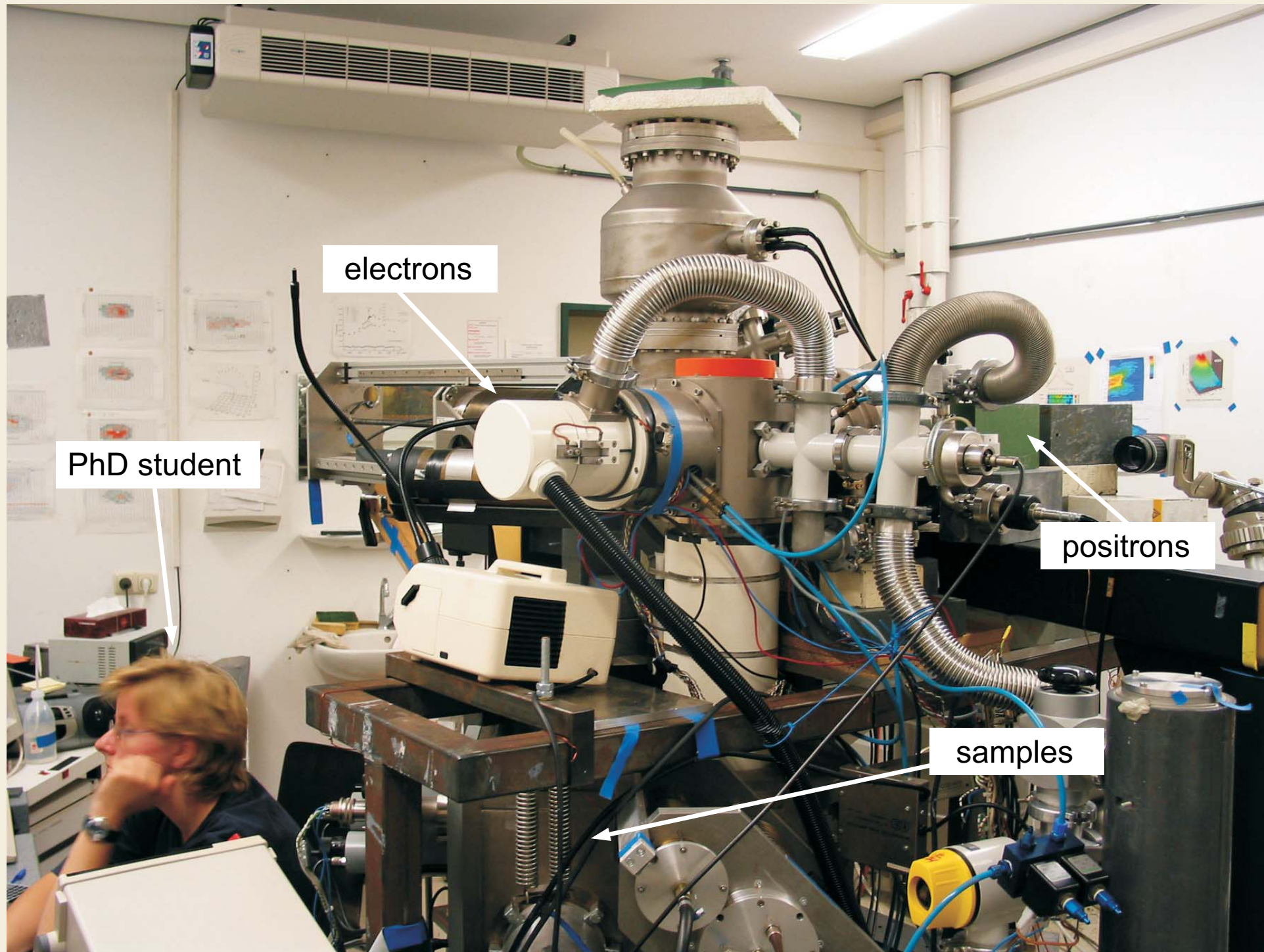
Beam diameter e^+ : 5 – 200 μm
 e^- : <12 nm

Source and moderator



Positron beam geometry (Simion 7)





electrons

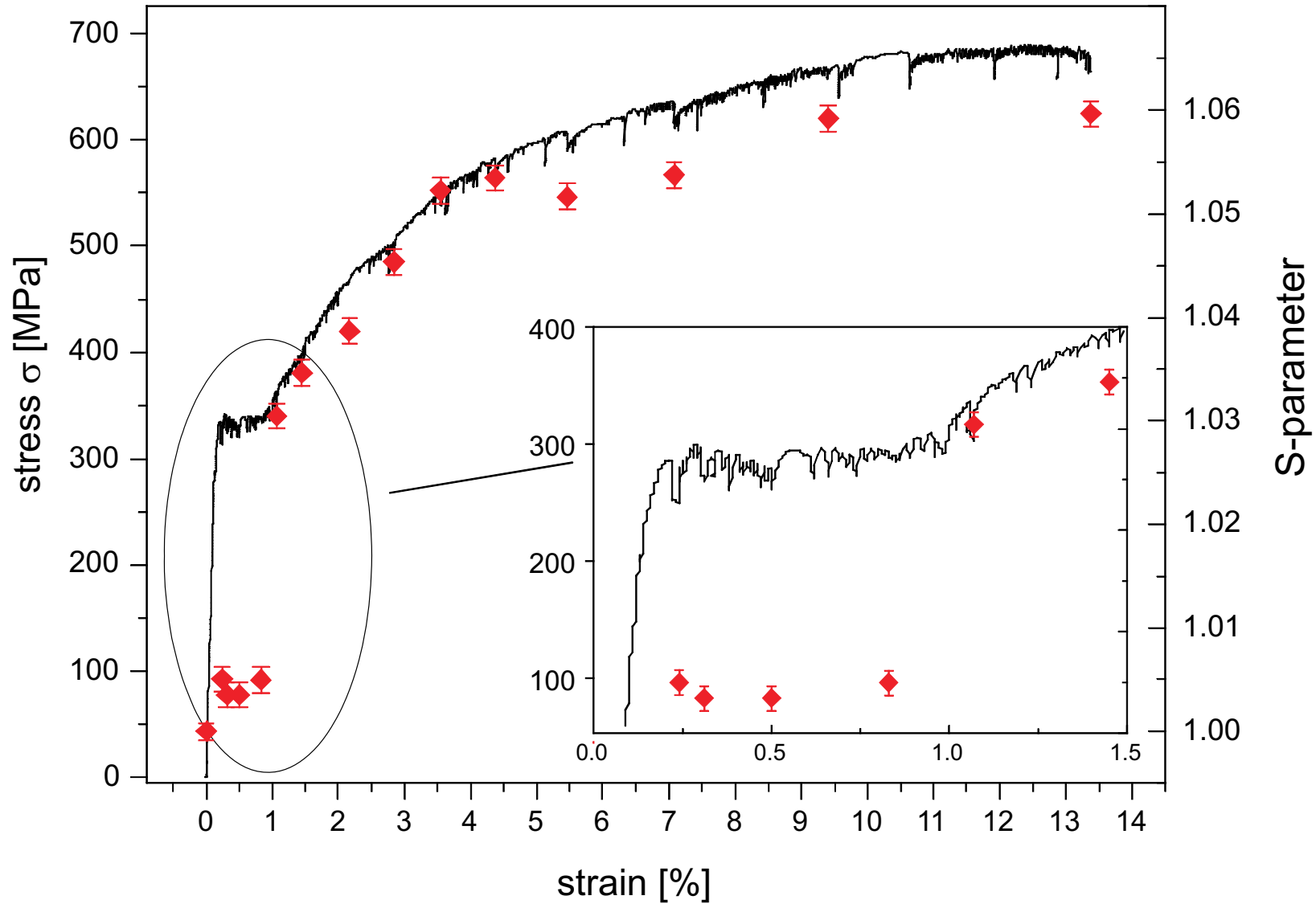
PhD student

positrons

samples

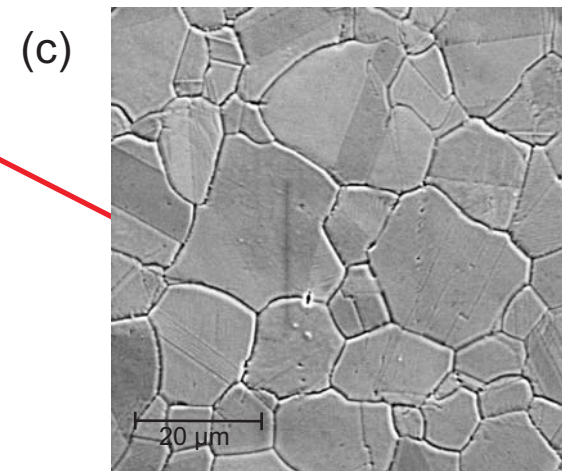
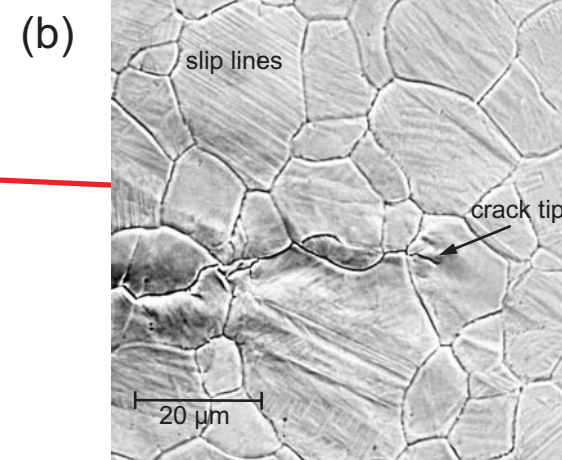
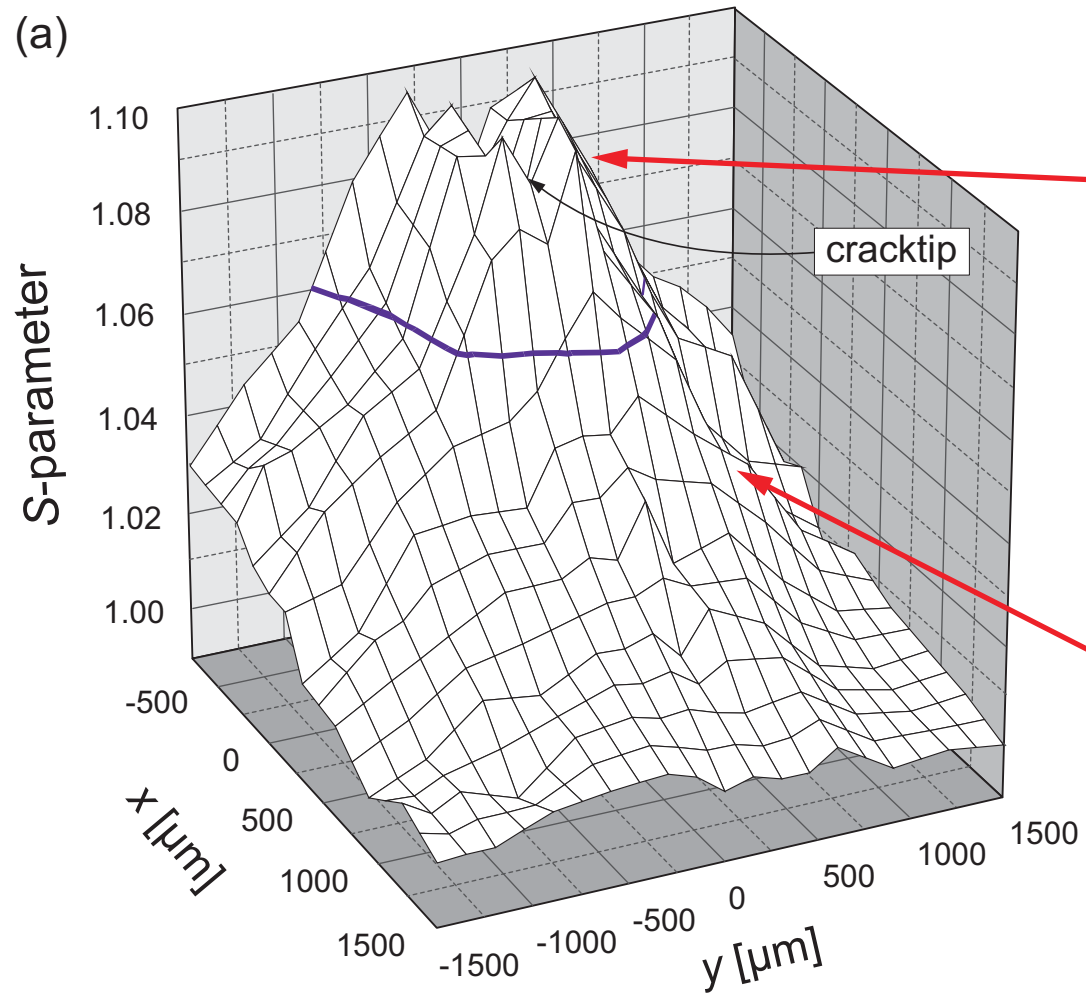
Tensile test: stress-strain-curve

well annealed carbon steel AISI 1045

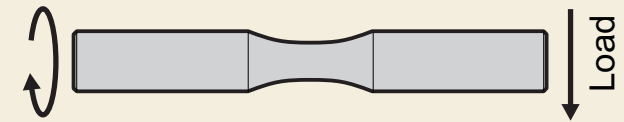


Cyclic plastic zone at a fatigue crack

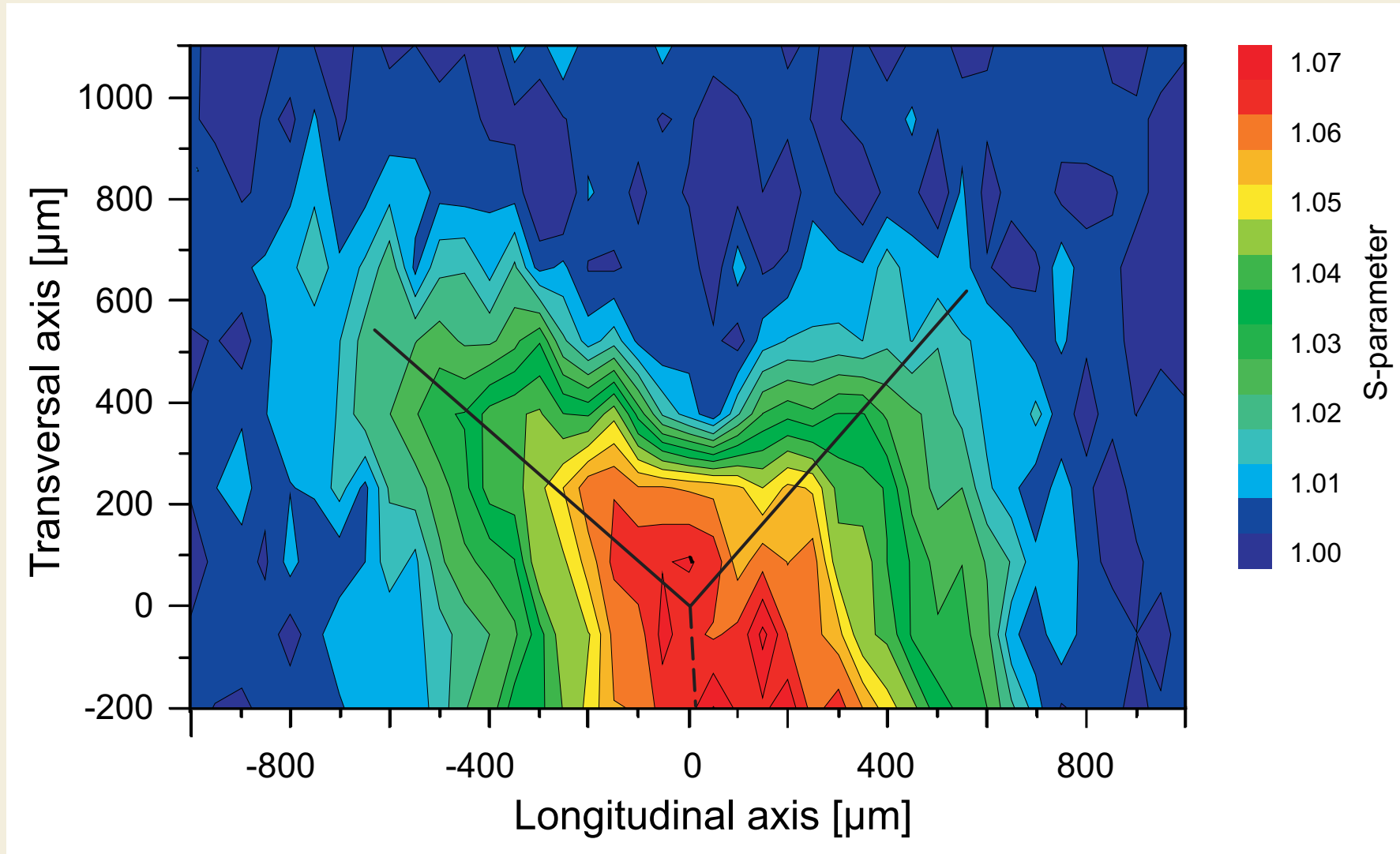
Compact tension fatigue: stainless steel AISI 321



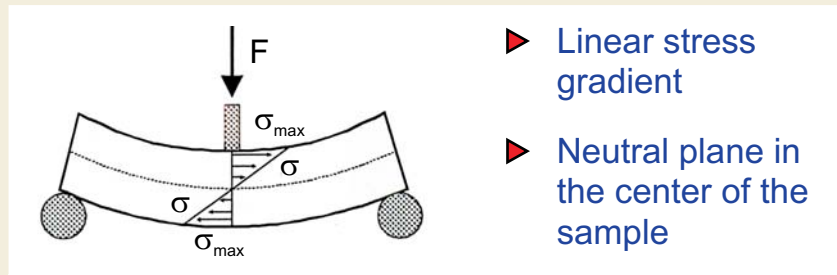
Cyclic plastic zone at a fatigue crack



Rotating bending fatigue: TiAl6V4



Three-point bending test on AISI 1045: Positrons / X-rays



X-rays:

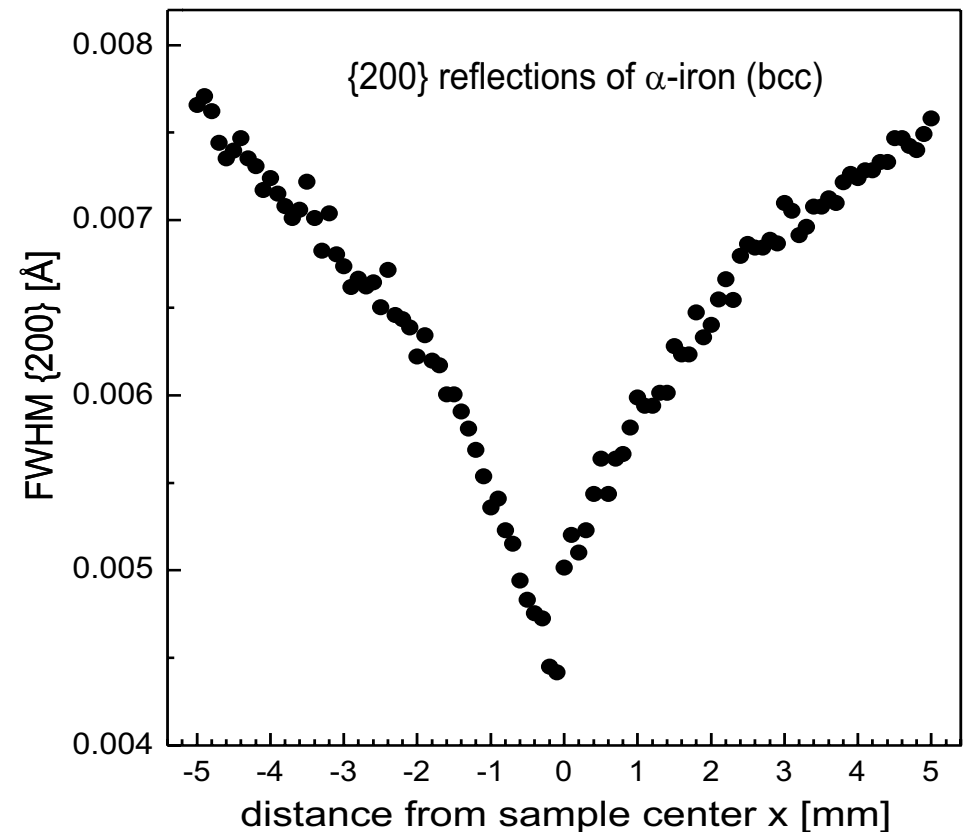
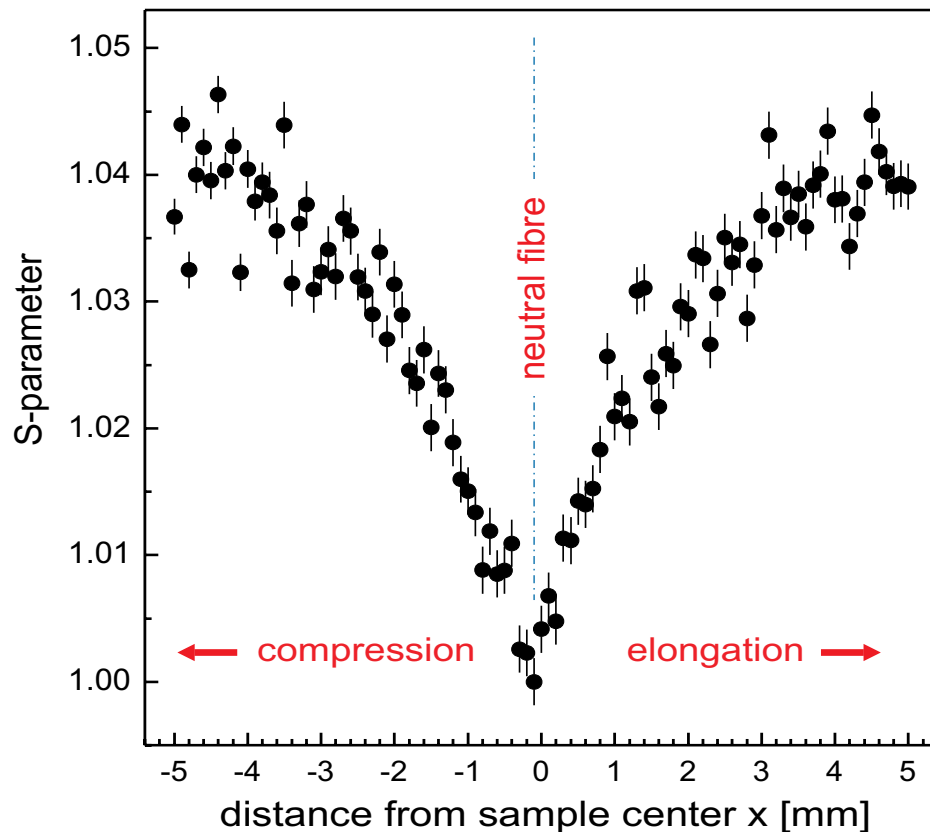
Lateral resolved Debye-Scherrer diffraction at 67 keV

Beam diameter: $1.5 \times 0.1 \text{ mm}^2$

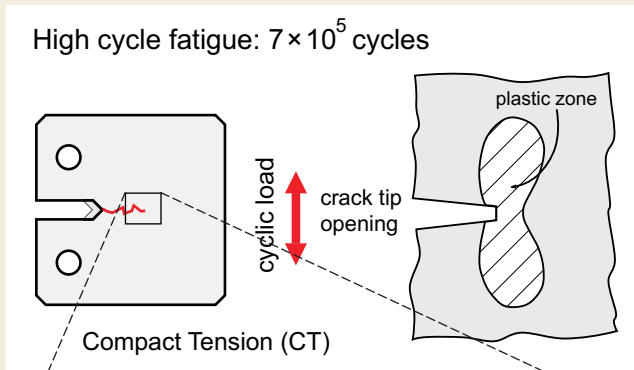
Powder condition: ~ 40000 grains

(hard X-ray beam-line at PETRA II, Desy/HASYLAB, Hamburg)

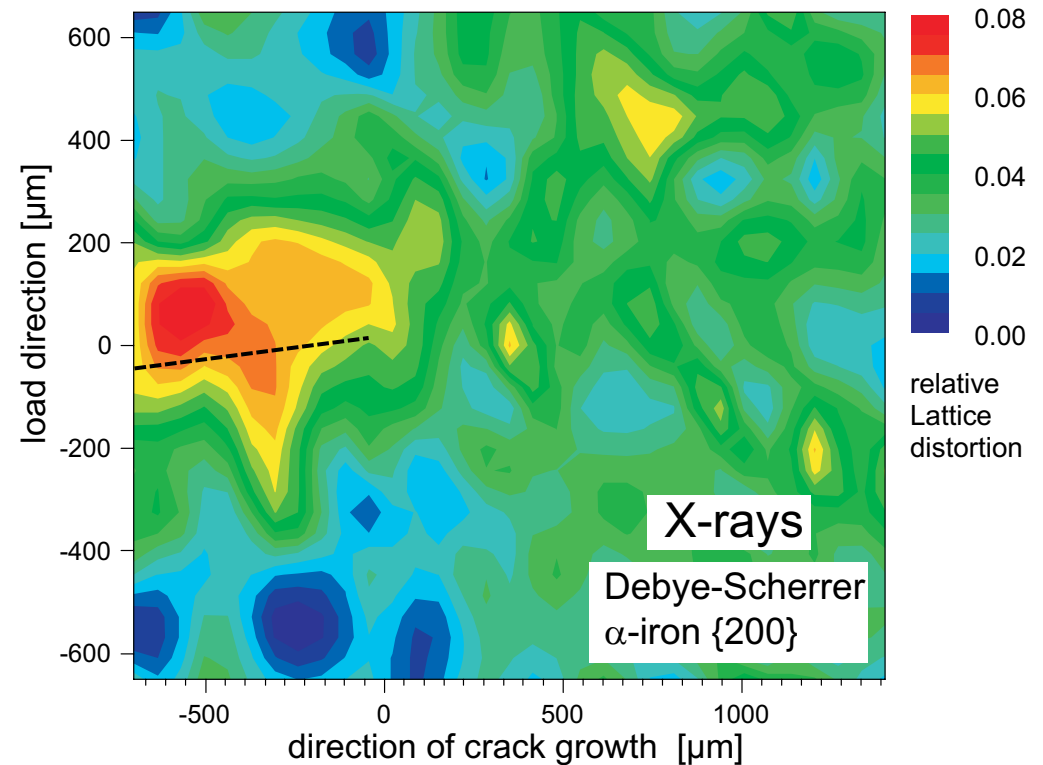
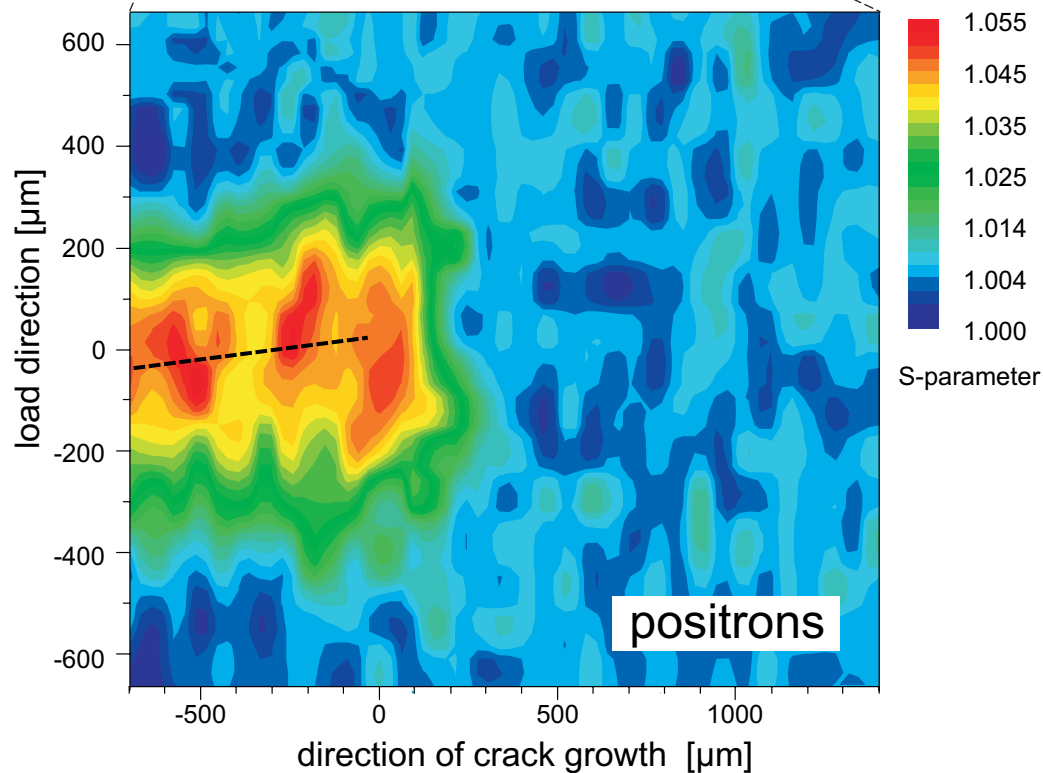
Positrons from BPM



Cracktip in CT geometry (AISI 1045): Positrons / X-rays

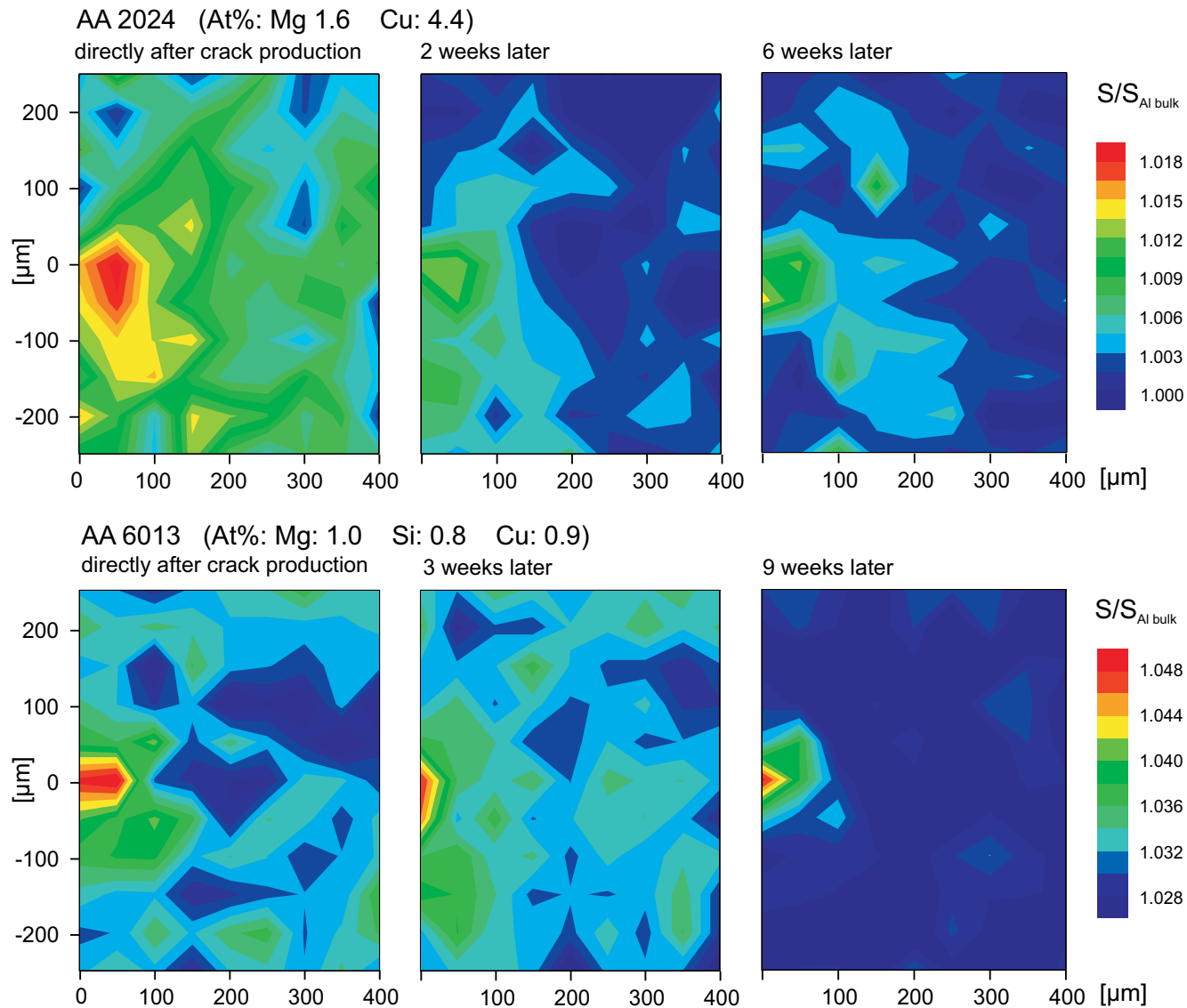


X-ray beam diameter: $0.1 \times 0.1 \text{ mm}^2$
Bad powder condition: ~ 1500 grains

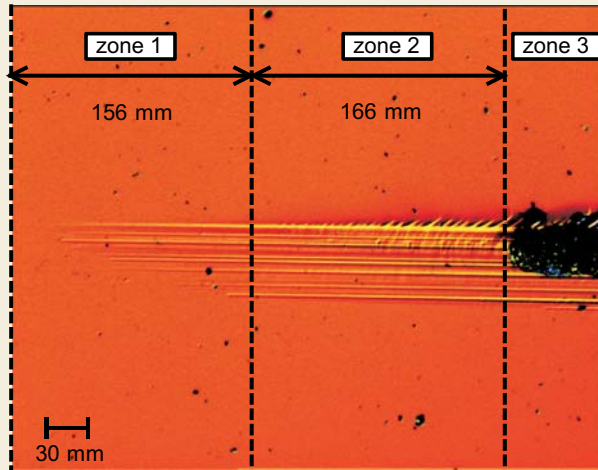


Hydrogen in aluminum alloys: AA 2024 and AA 6013

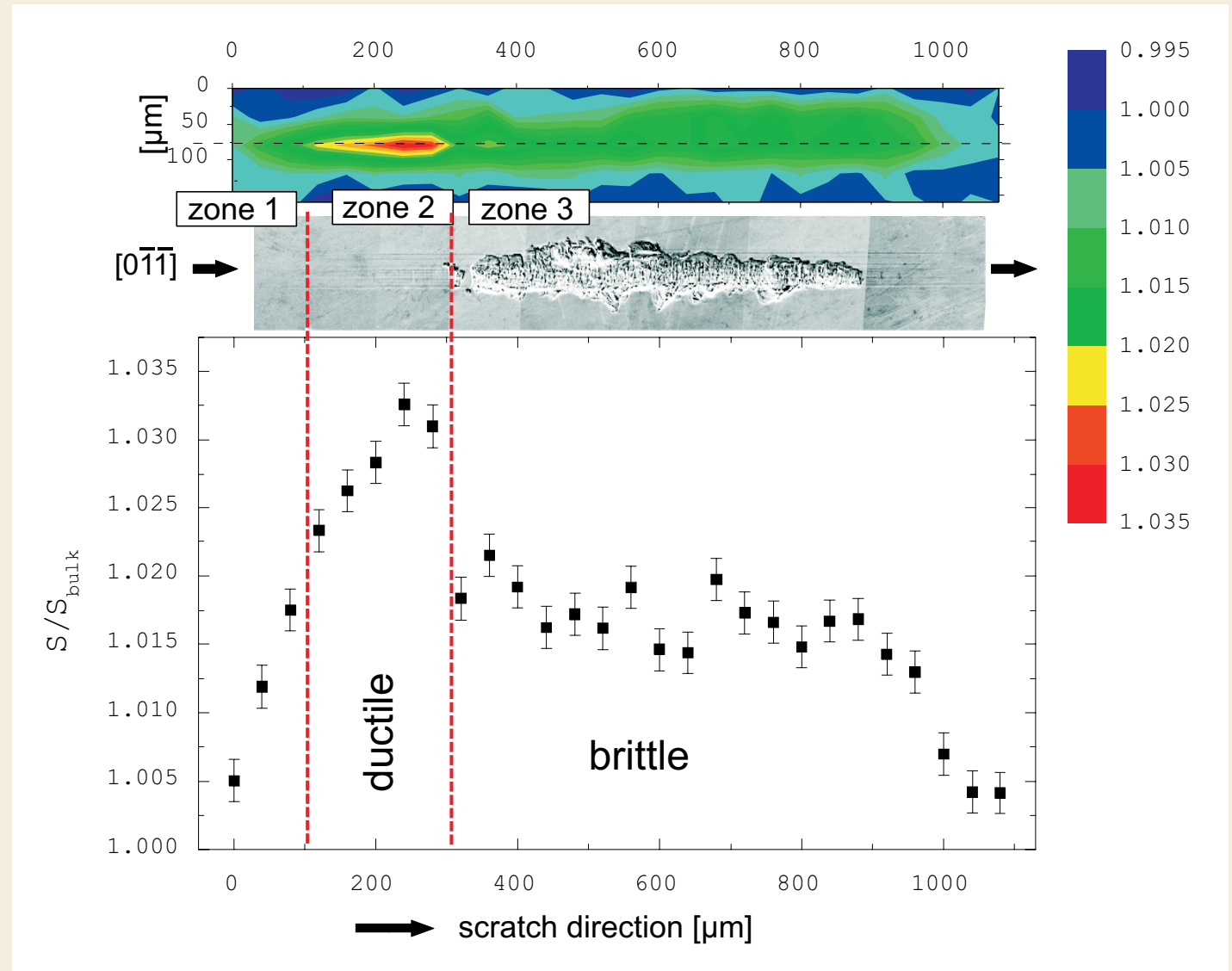
cyclic plastic zones produced in corrosive environment:
diffusion of vacancies hindered by hydrogen



Micro-scratch on GaAs surface

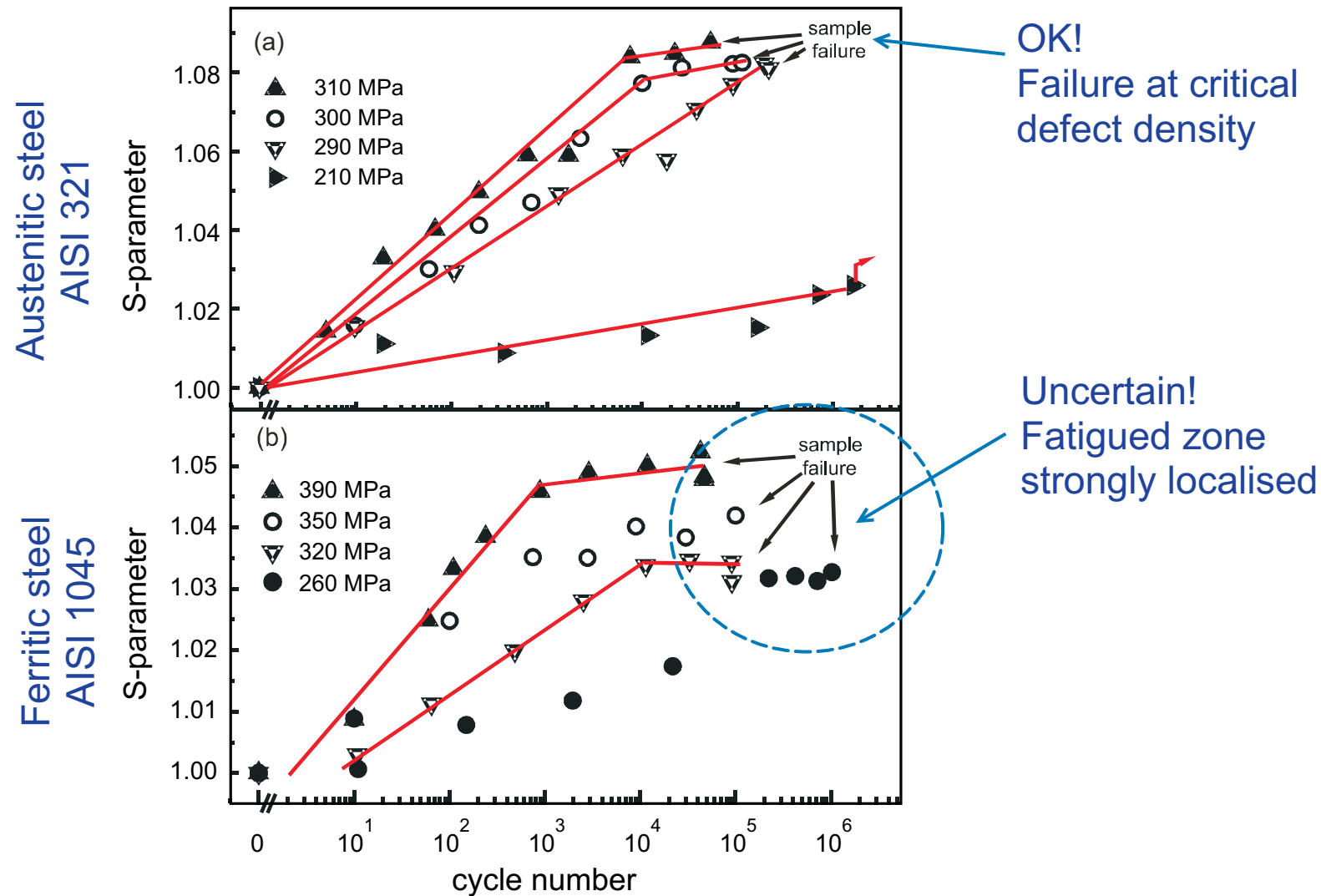


- ▶ Ductile behavior:
Plasticity due to
hydrostatic pressure

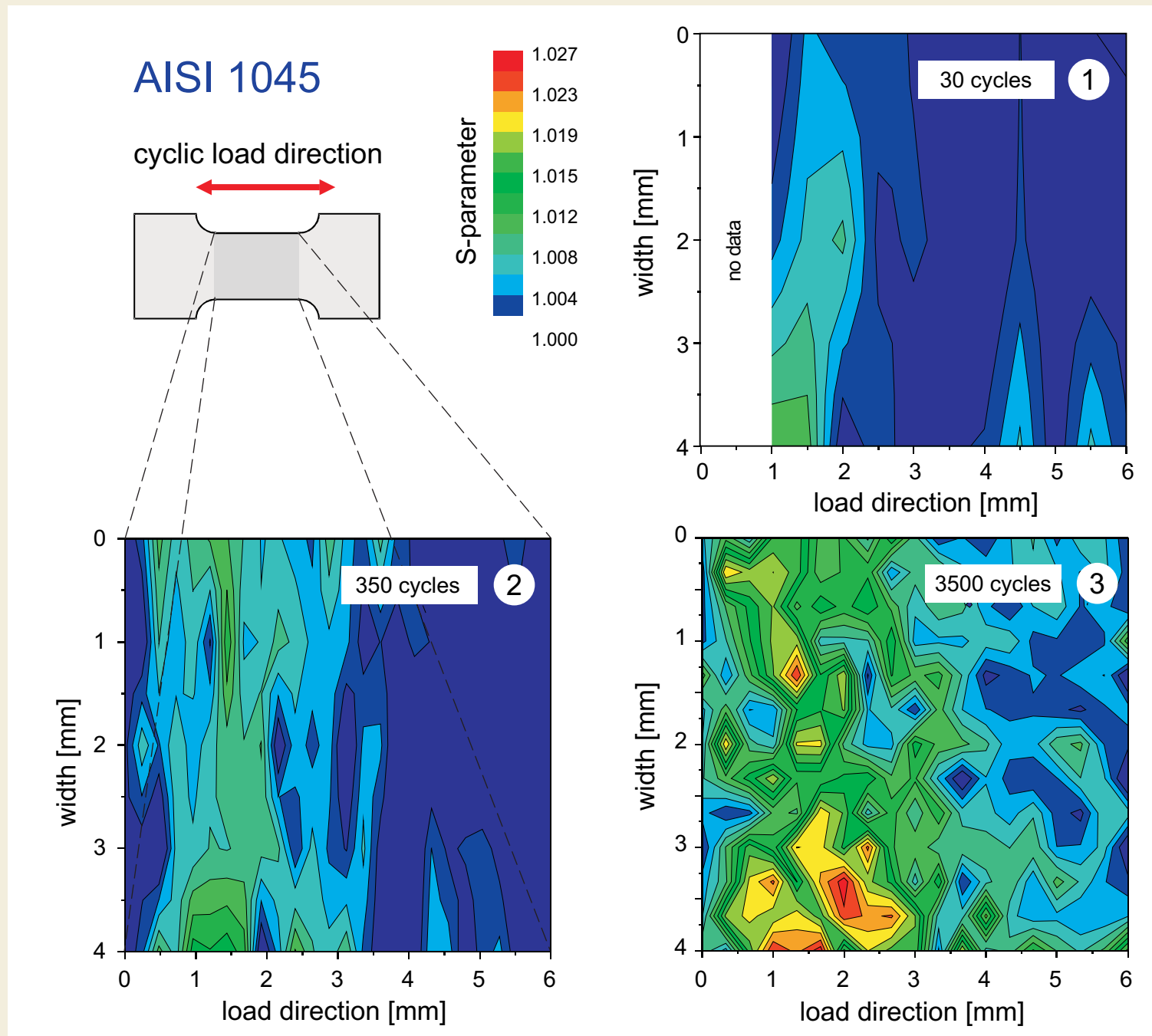


Prediction of fatigue failure: Defect density as precursor for fatigue failure

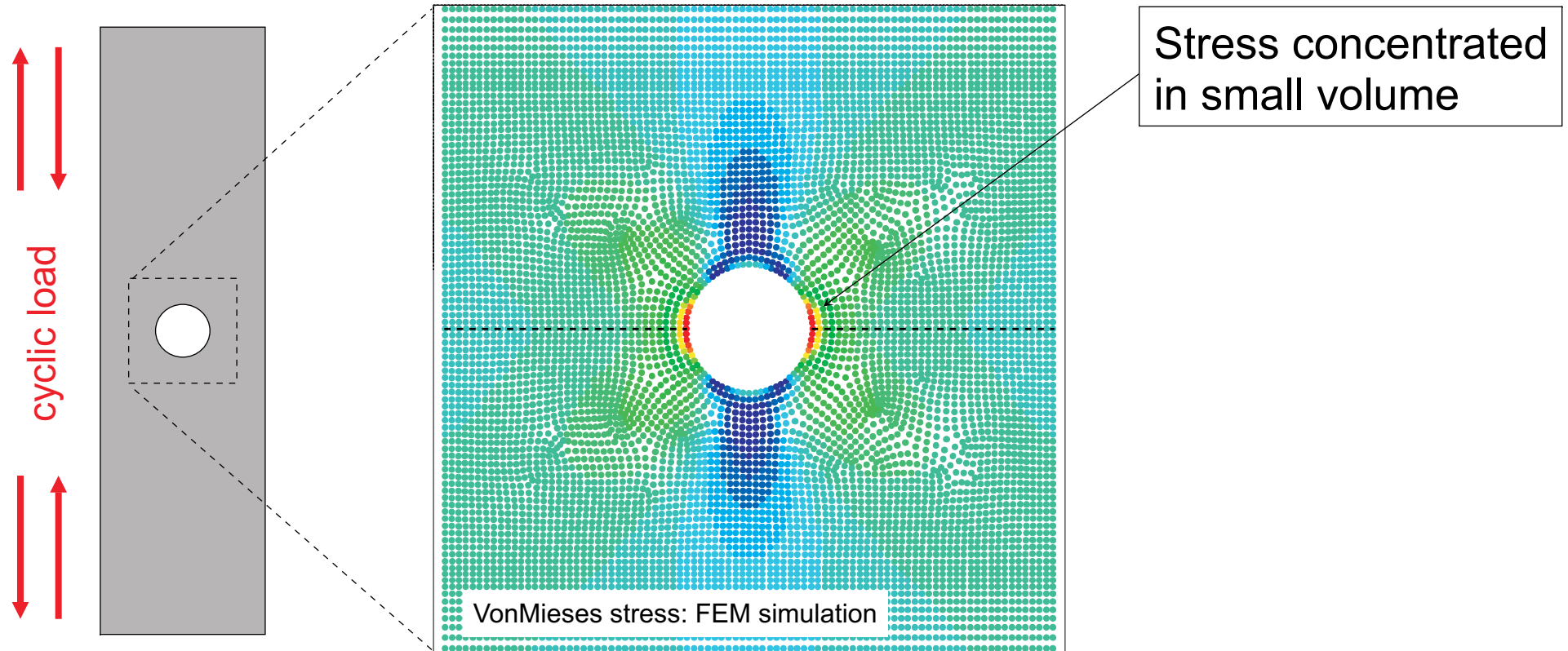
▶ Material failure ➔ Critical defect density ↔ Critical S-parameter



Localization: Lateral defect structures during fatigue



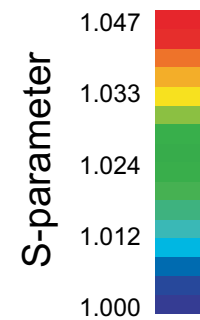
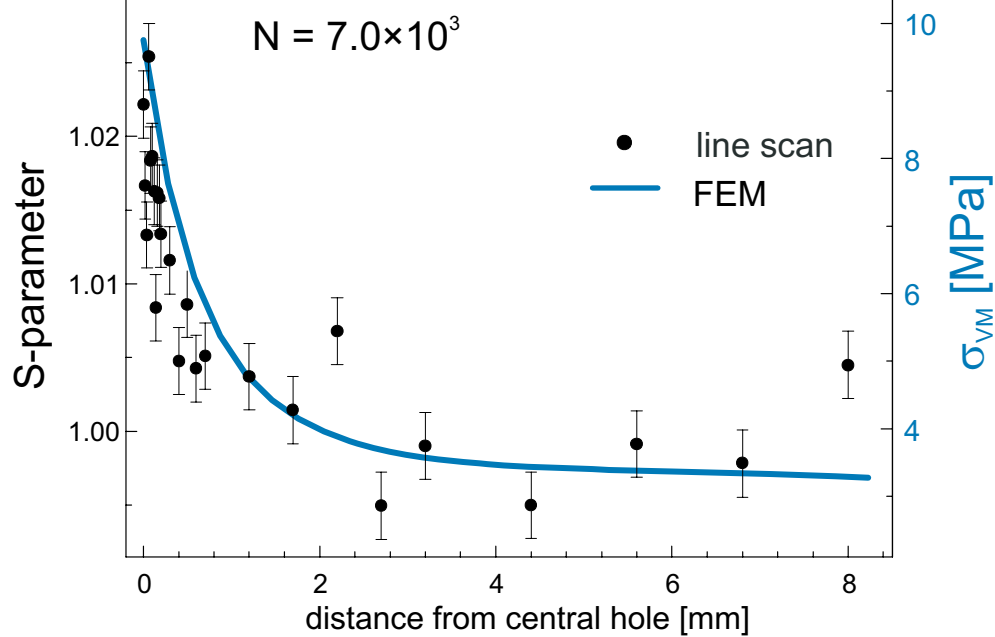
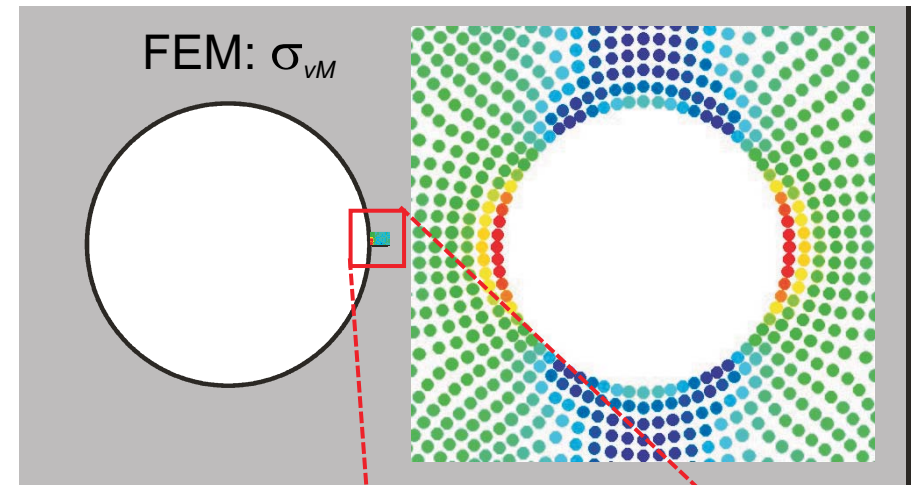
Geometry with defined stress concentration



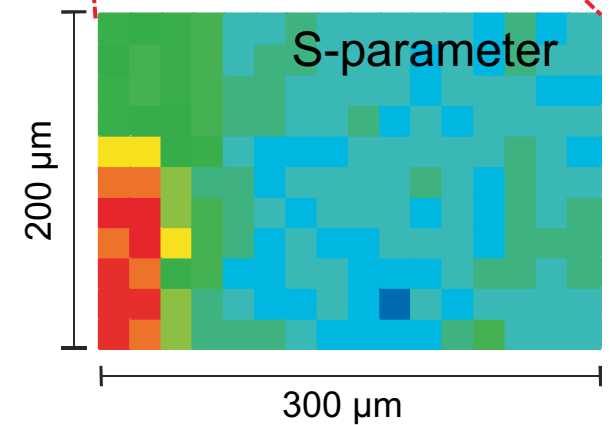
- ▶ FEM: VonMises-stress σ_{VM}
- ▶ Strongly localised defect distribution expected

Positron results

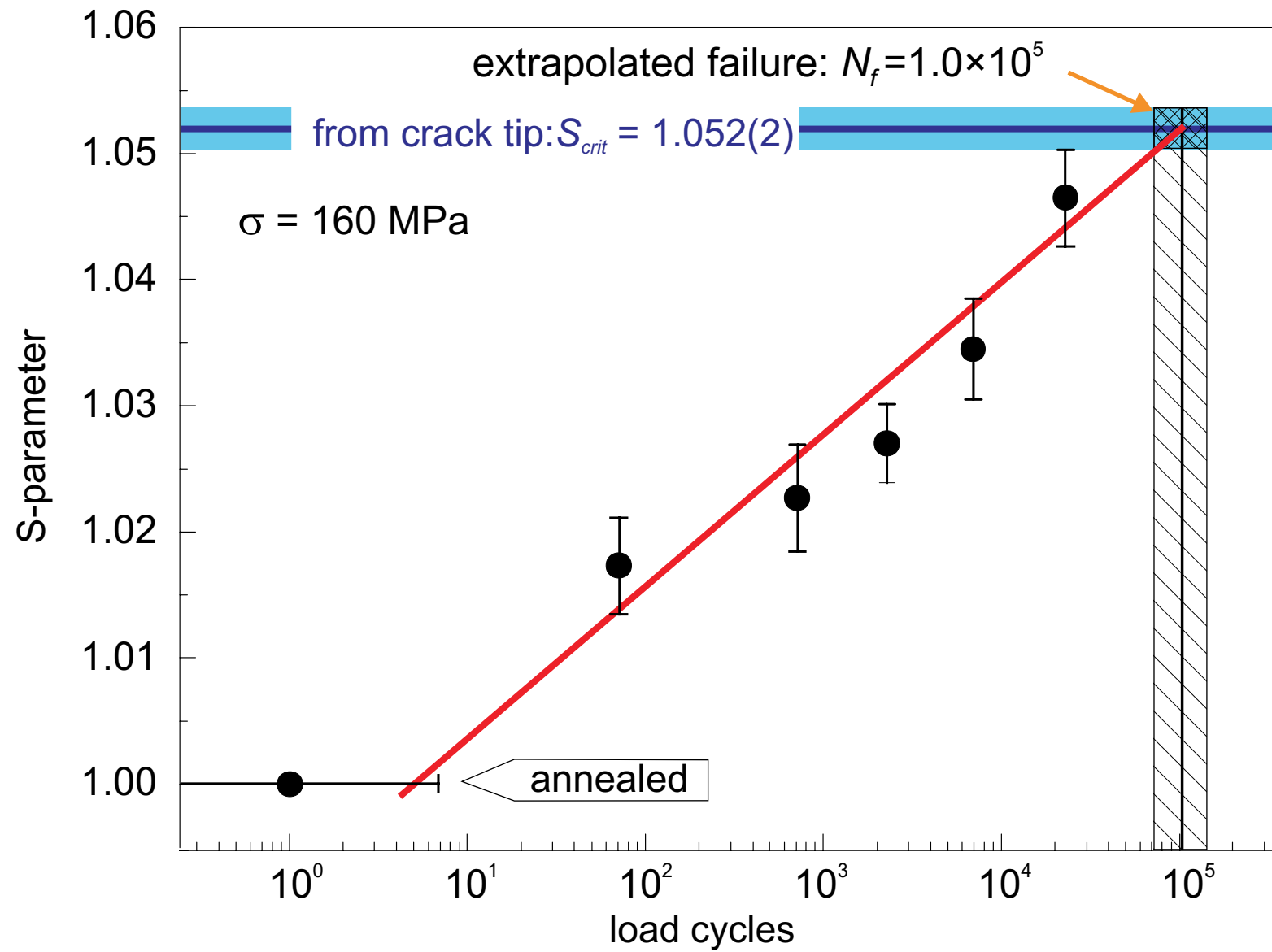
Cyclic load $\sigma = 160$ MPa



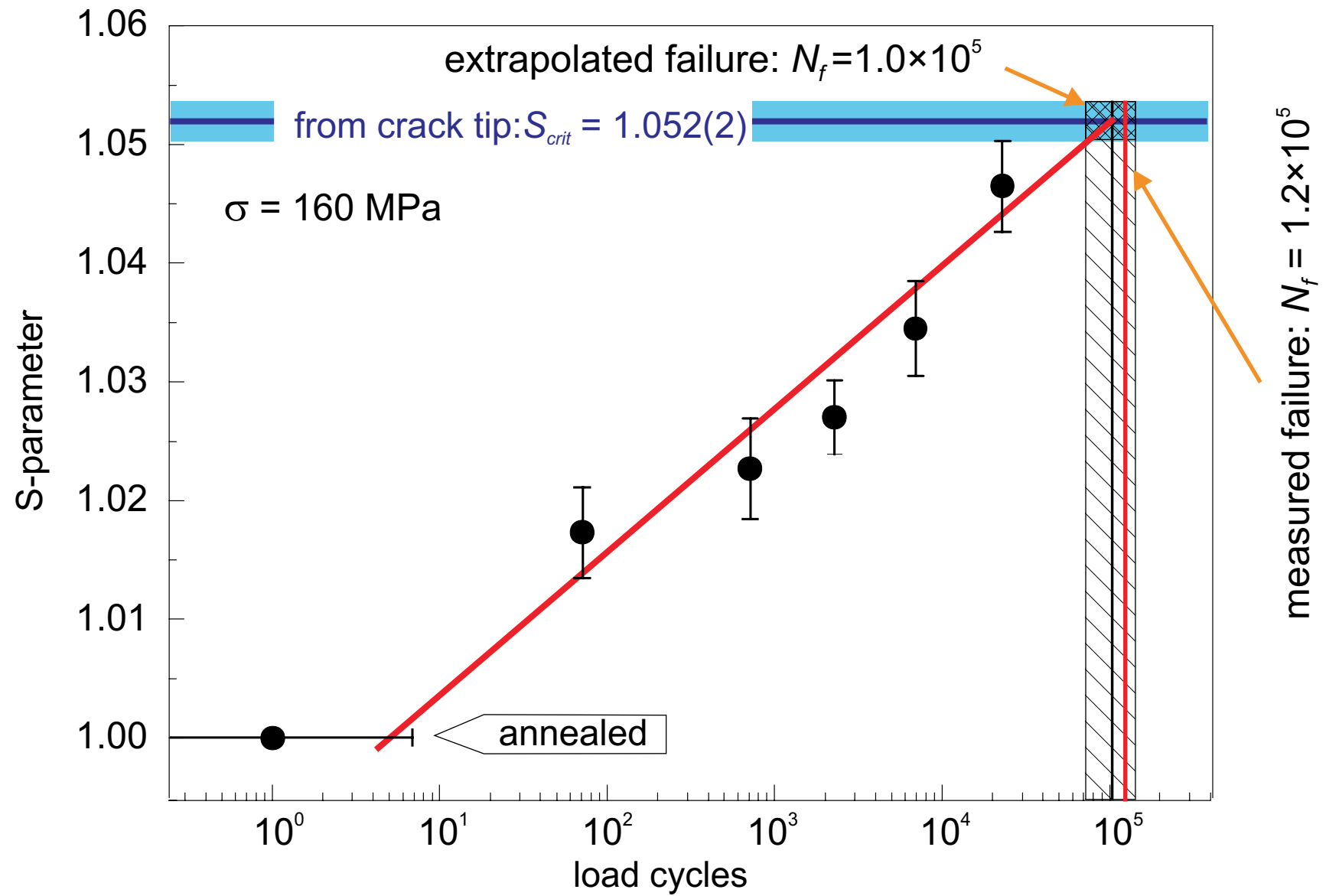
$N = 2.2 \times 10^4$



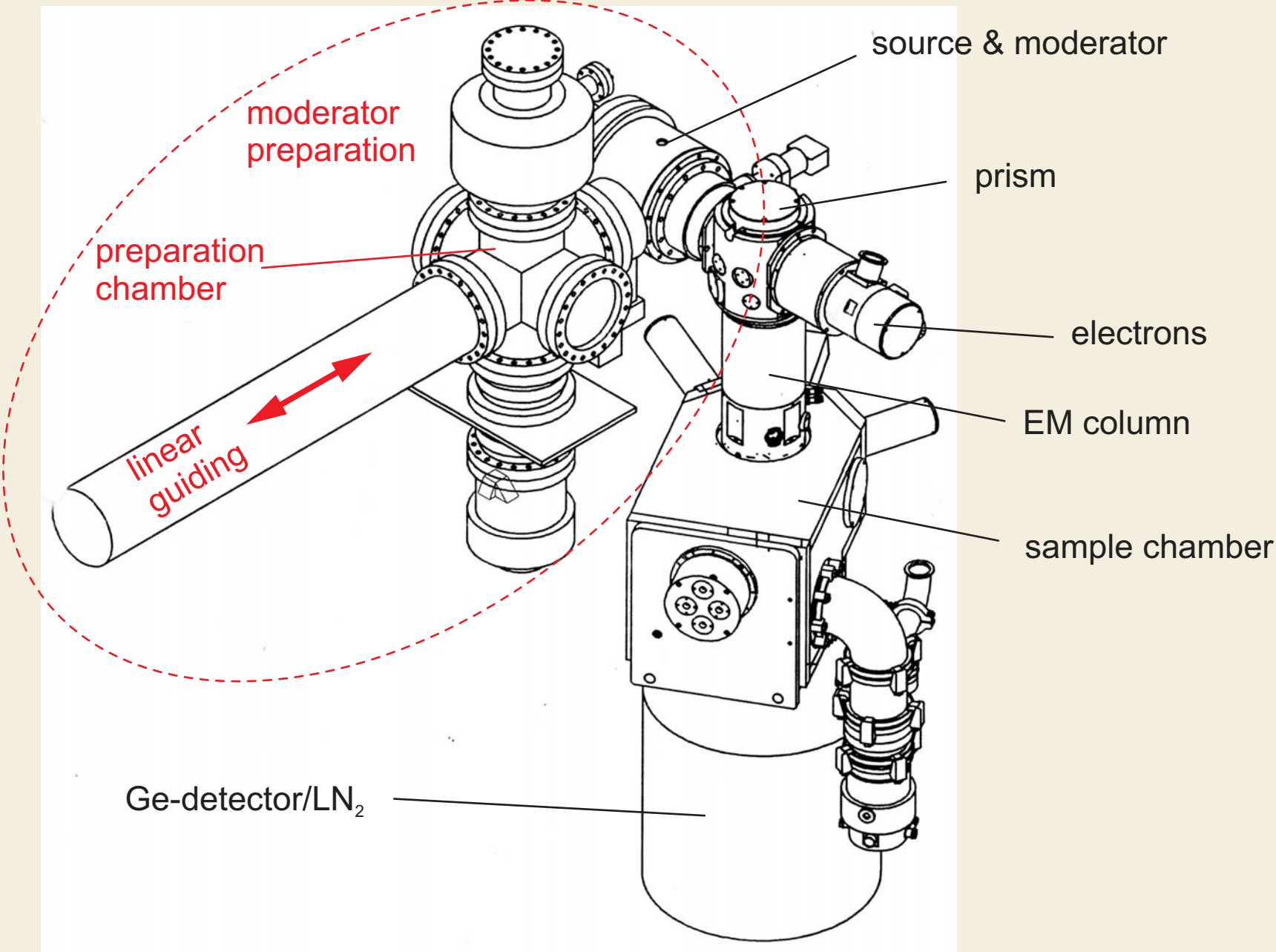
Failure prediction using the critical defect density



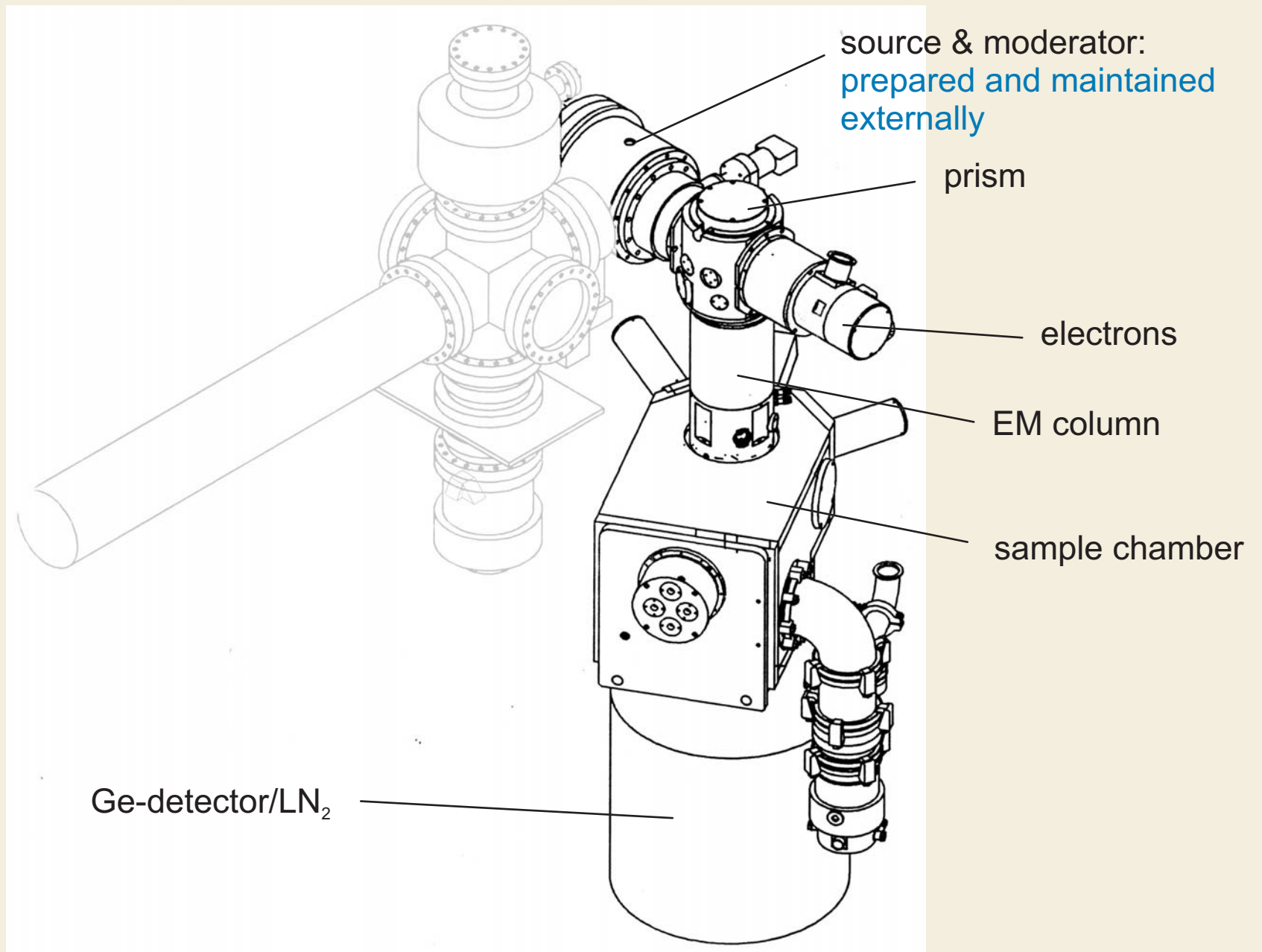
Failure prediction using the critical defect density



A commercial SPM...



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