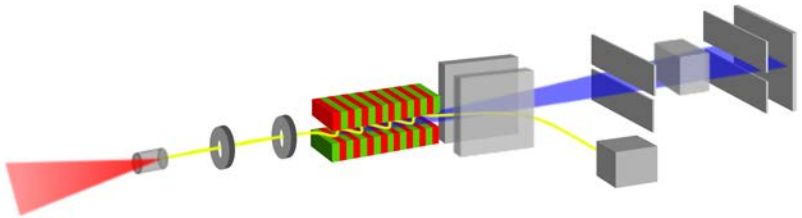
HelmholtzZentrum münchen
German Research Center for Environmental Health



Munich-Centre for
Advanced Photonics (MAP)

LAOLA
Laboratory for Laser- and beam-driven plasma Acceleration

Introduction into brillant X-ray sources for medical imaging

Bernhard Müller[1,2], Florian Grüner[2,3], Christoph Hoeschen[1]

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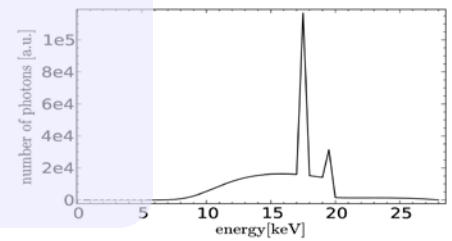
2: Ludwig-Maximilian-Universität München, Fakultät für Physik
3: University of Hamburg, Institute of Experimental Physics

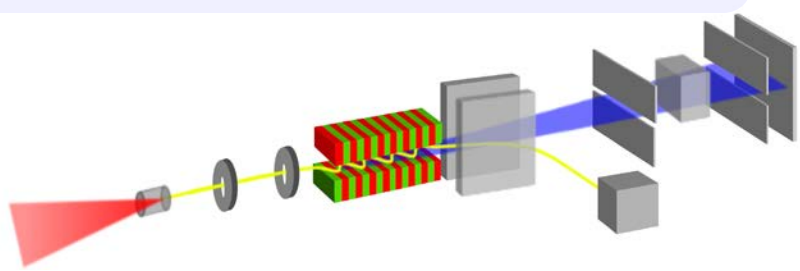
Ultimate goal: dose/contrast agent reduction

- disadvantages of x-ray tubes:
  - polychromatic spektrum → low CNR/Dose
  - focal spot size → limited spatial resolution (especially for magnification)



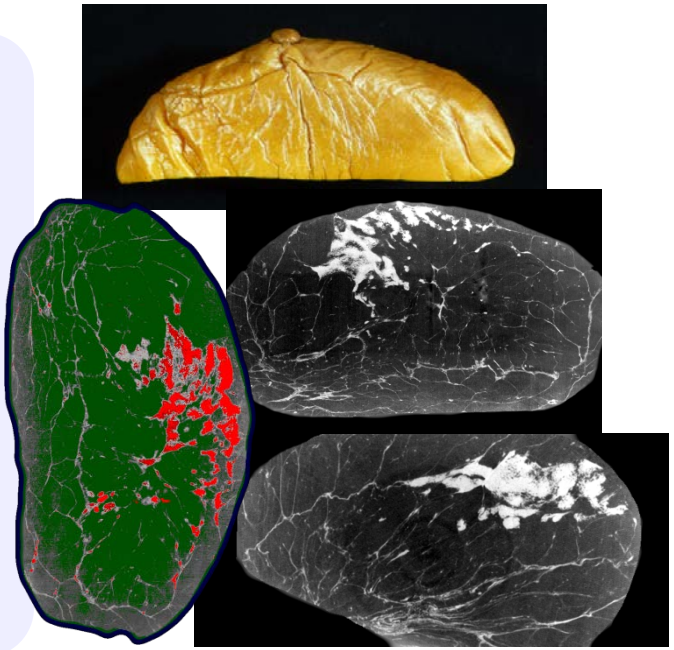
- advantages of undulator sources:
  - quasi-monochromatic (few %) → high CNR/dose
  - laminar beam geometry → scatter reduction
  - low divergence → high spatial resolution
  - tunable energy

high brilliance

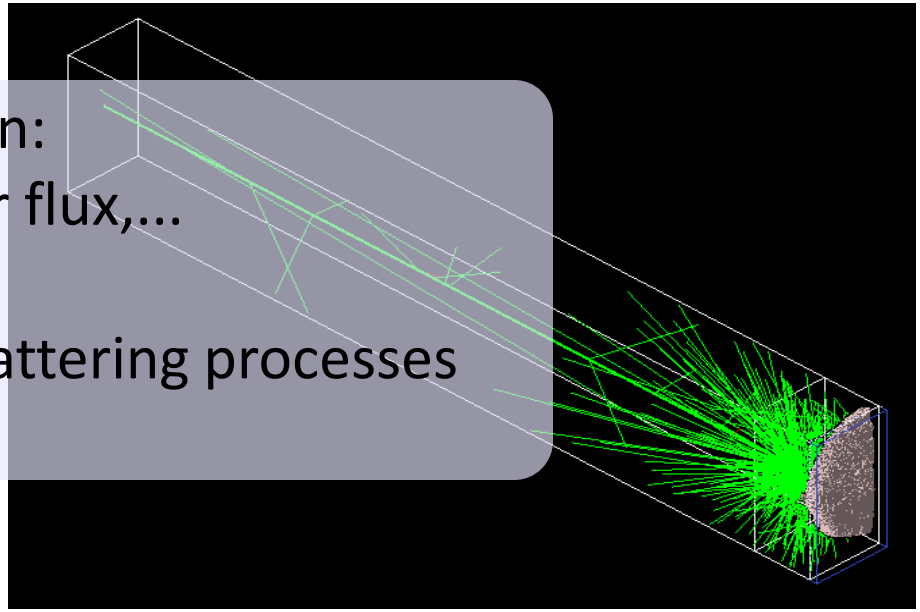


Monte Carlo simulation of mammography

- high resolution voxemodels of breast
- created from CT-scans
  of anatomical breast specimens
- voxel size: 60 x 60 x 60 µm³
- segmentation in different tissues:
  - adipose
  - glandular
  - skin

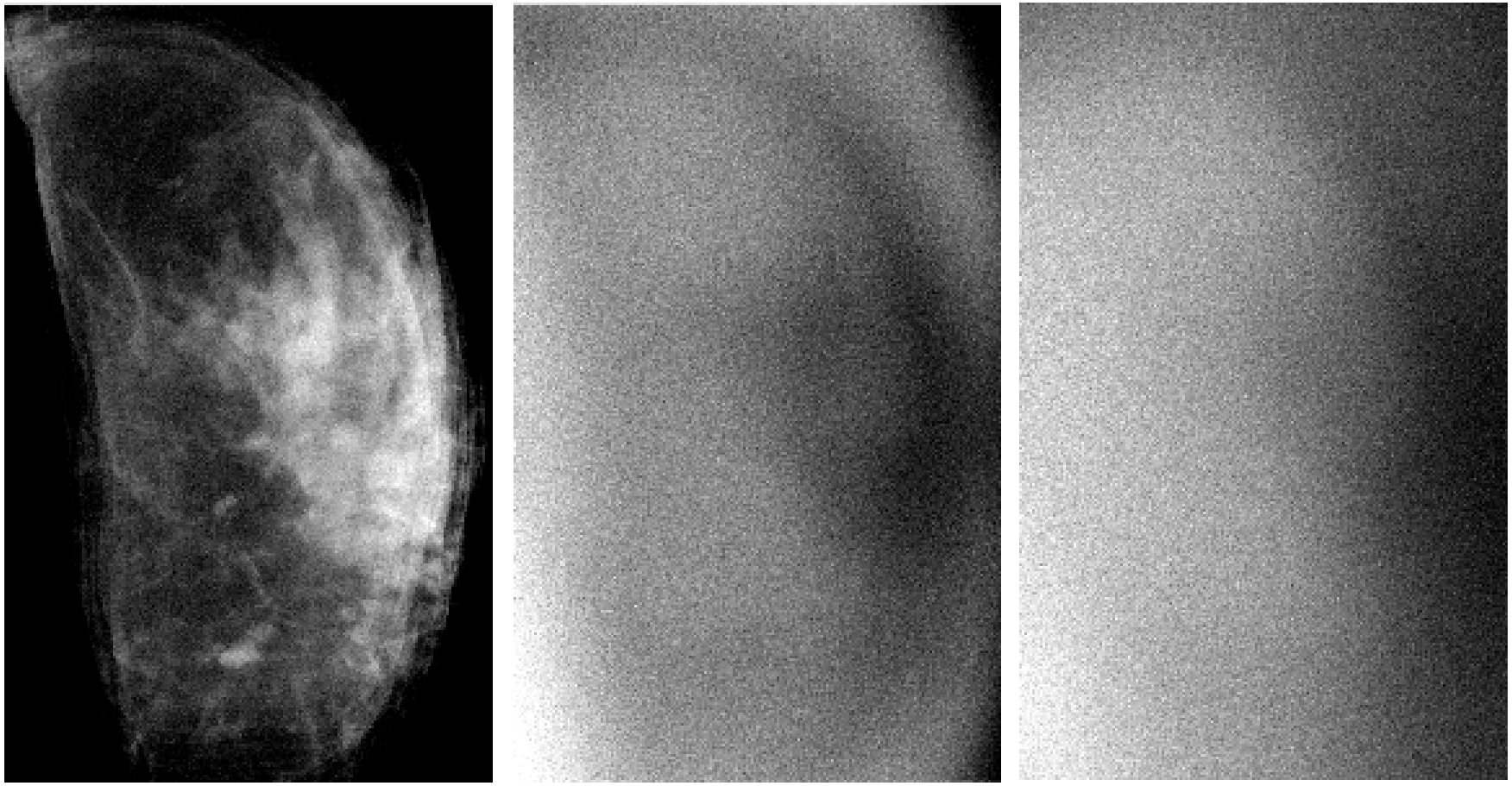


- using brilliant undulator radiation:
  beam geometry, spectral angular flux,...
- pulsed scanning geometry
- simulation of absorption and scattering processes
  with Geant4-Software-Toolkit



Simulation of mammography

0.2 mGy average glandular dose at ~10^{11} photons

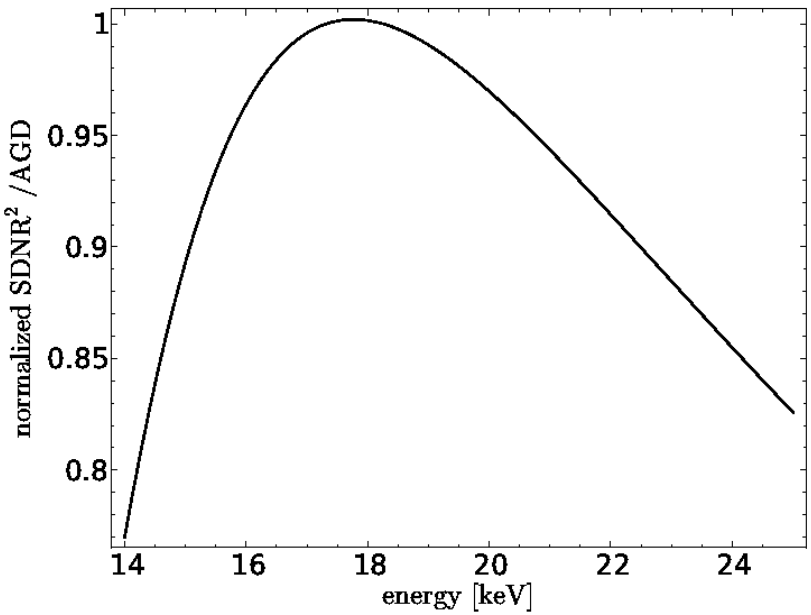


(a) primary

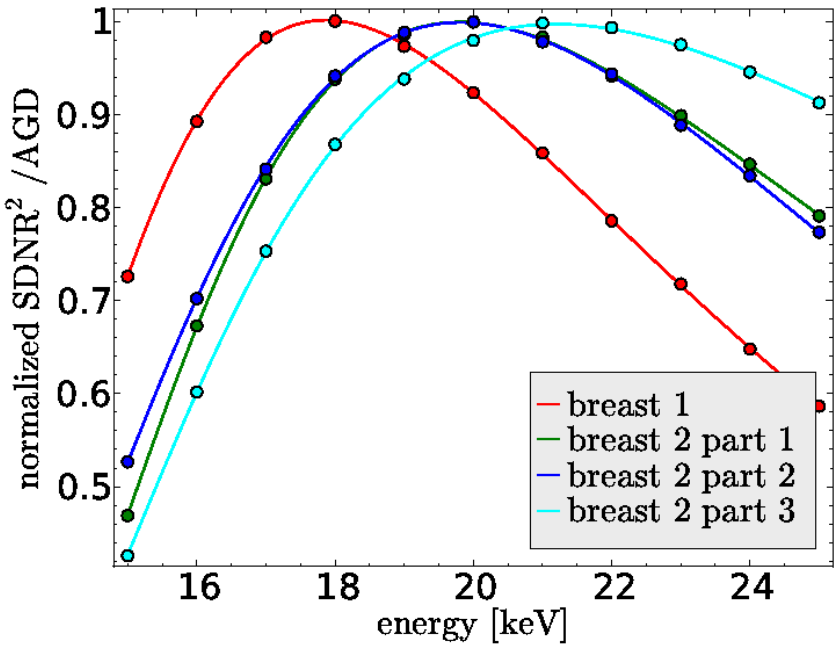
(b) Rayleigh

(c) Compton

optimal X-ray energy



analytical **model**

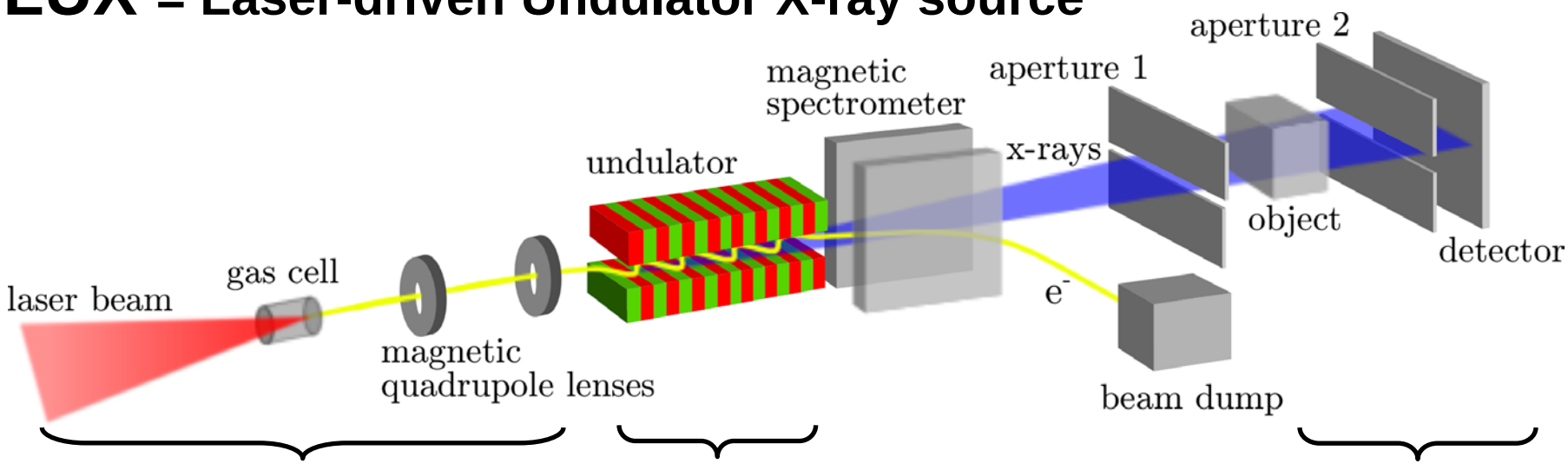


(b)

simulation for 3 different breast models

→ requires **tunable** source

LUX = Laser-driven Undulator X-ray source

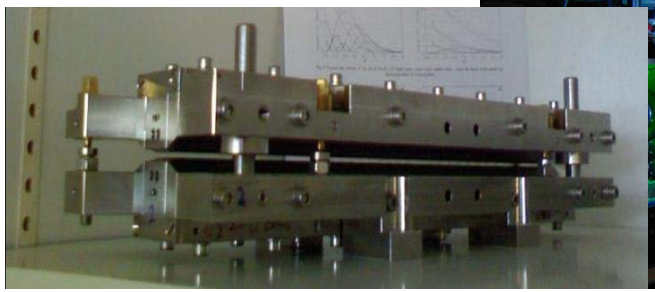


Electron acceleration:

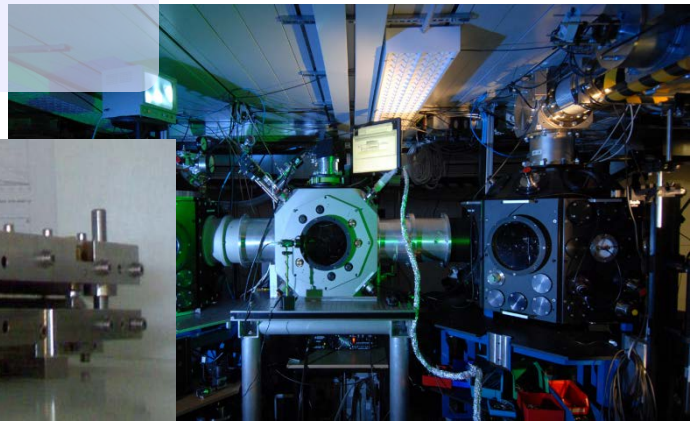
- compact
- stability through band-pass property

Synchrotron radiation:

- narrow bandwidth
- low divergence



imaging

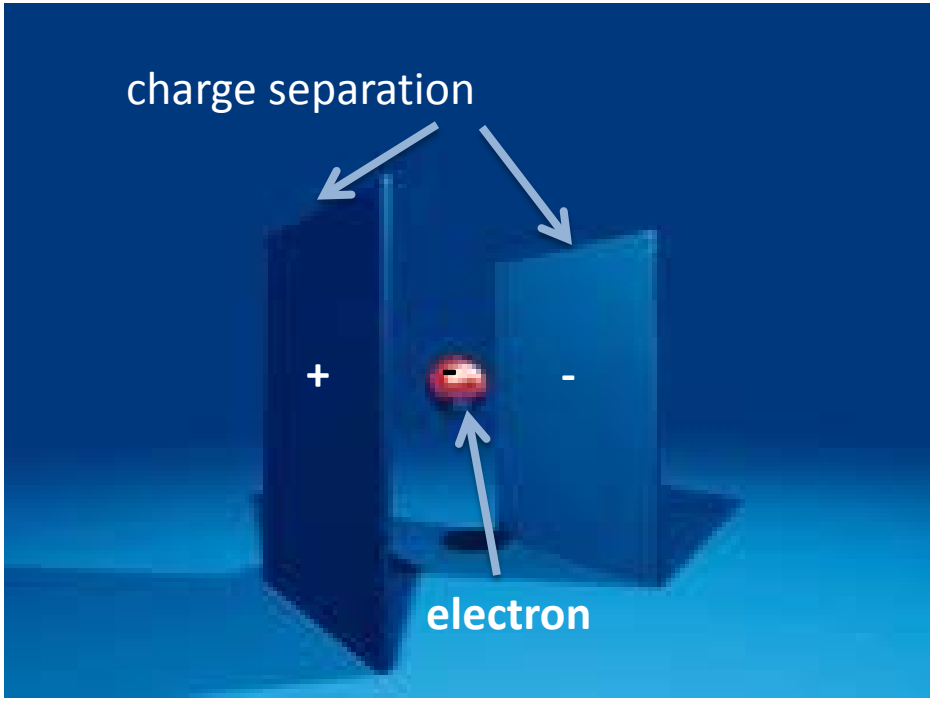


1. M. Fuchs et al., *Laser-driven soft-X-ray undulator source, Nature Physics 5, 826 (2009)*
2. F. Grüner et al., *Design considerations for table-top, laser-based VUV and X-ray free electron lasers, Applied Physics B, Volume 86, Number 3, February 2007 , pp. 431-435(5)*

basic principle of any accelerator

one needs an electric field…

…charged particles are then accelerated



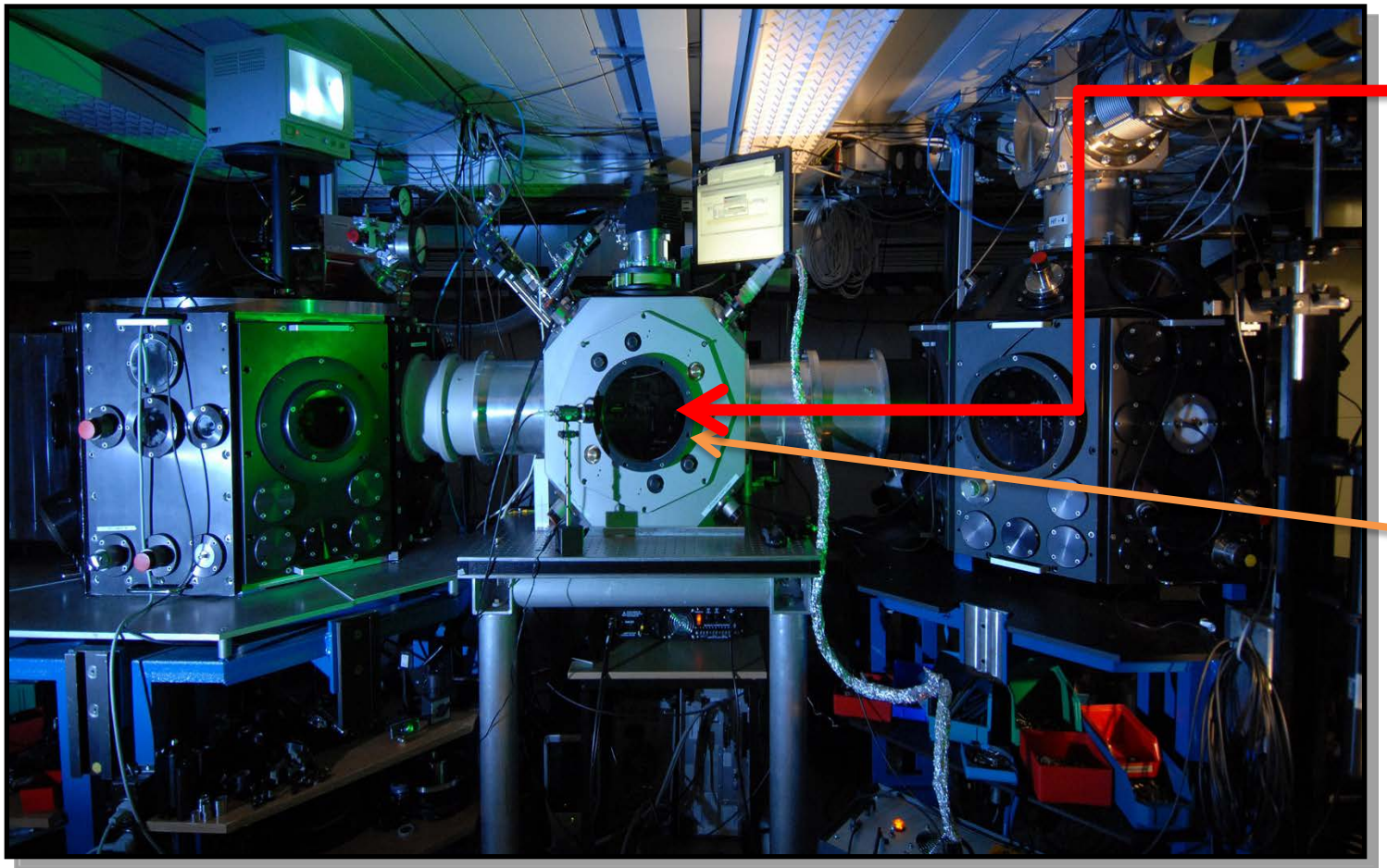
accelerators can be quite large…

kilometer
long!!!!....

but also quite small…

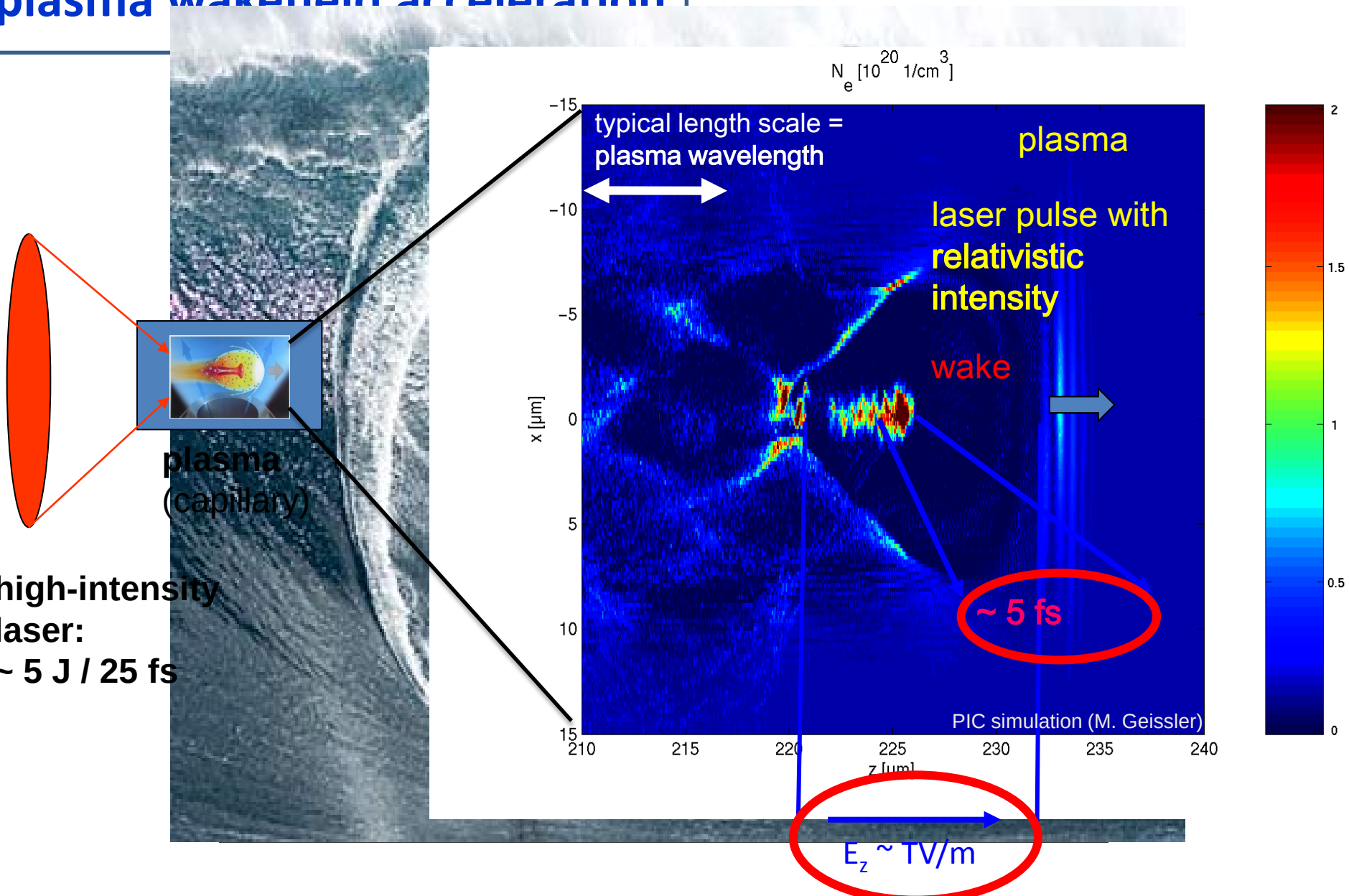
lab setup of a Laser-Plasma-Accelerator at MPQ (S. Karsch et al.)

pulse of a high-Power laser



<u>plasma cell</u>:
cm short!!!!….

plasma wakefield acceleration



Outlook

- further synchrotron experiments at **DESY** for quantification of sensitivity and CNR and definition of optimal contrast material and system geometry
- energy resolving (or energy specific) **detector** required, optimally rather large
- with **LUX** an integration into a clinical scanner appears conceivable, offering a perspective of non-radioactive molecular imaging in vivo.