X-ray imaging

F. Grüner

Röntgen’s first “medical imaging”

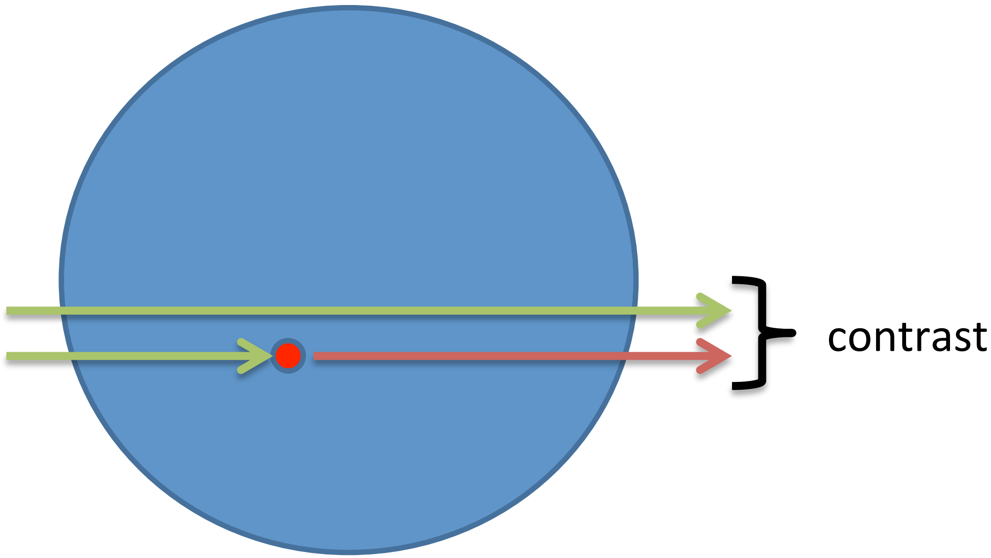
Improvements….

System-specific image processing

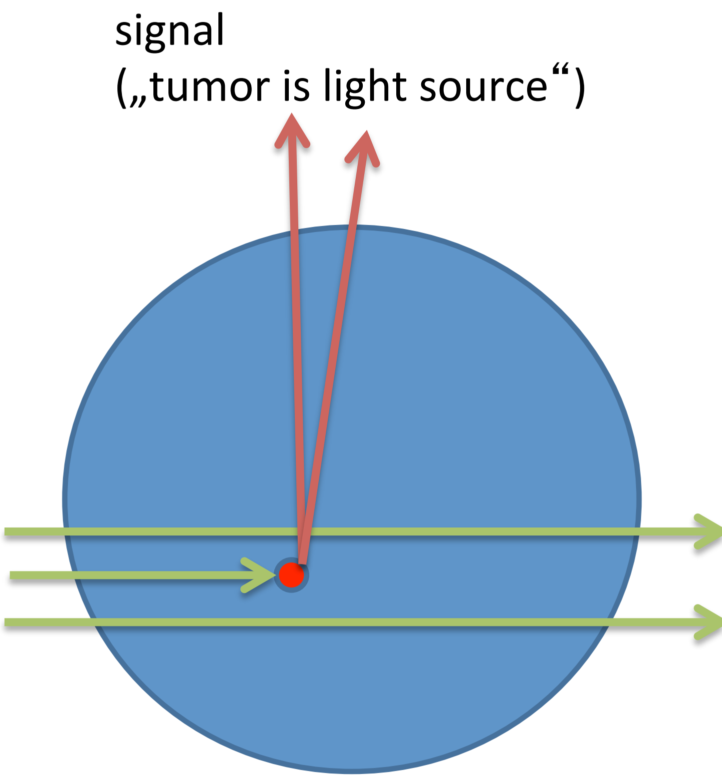
Adaptive auto-windowing algorithm

Basic principles

X-ray absorption/phase **contrast** imaging



X-ray **fluorescence**

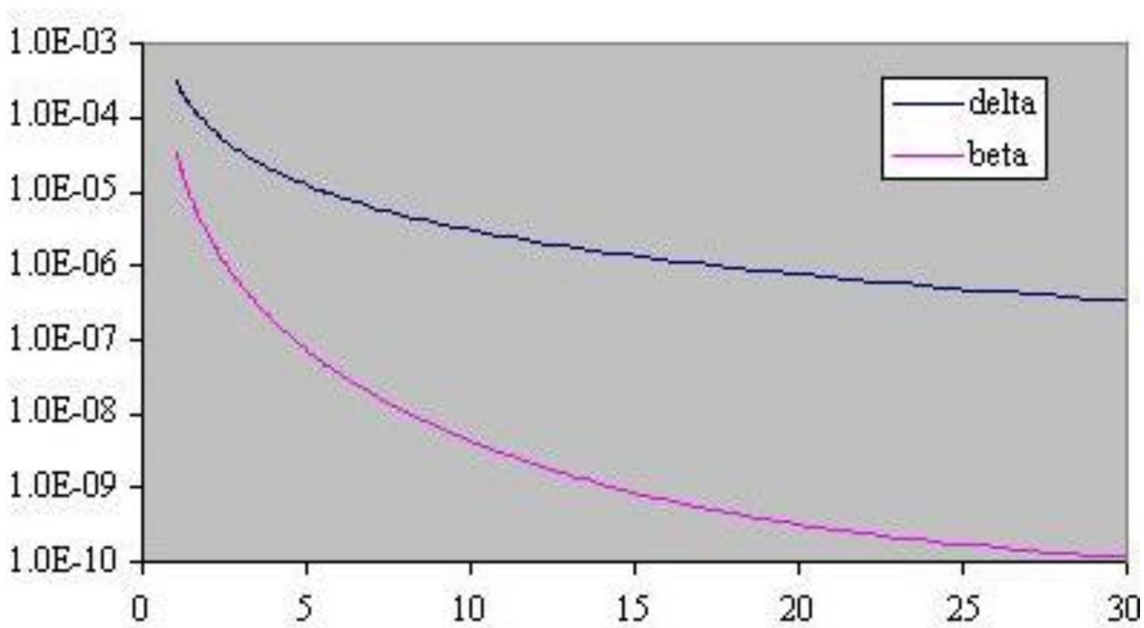


absorption vs phase contrast imaging

refractive index is written as n = 1 – *d* + iß

phase contrast

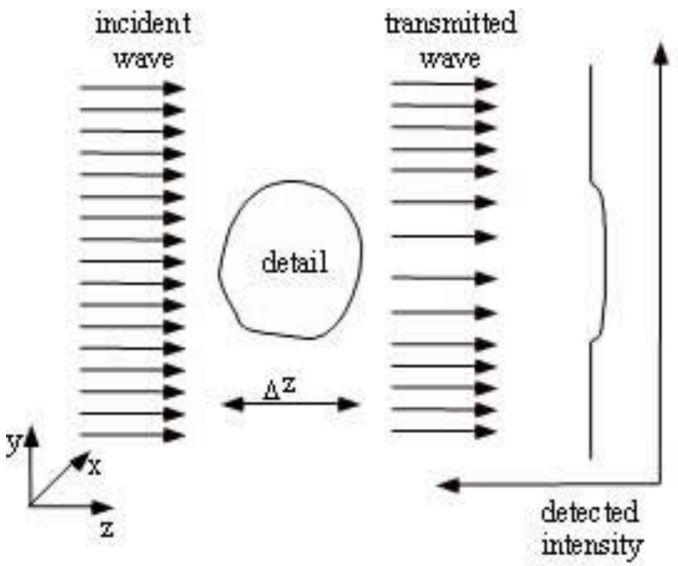
absorption



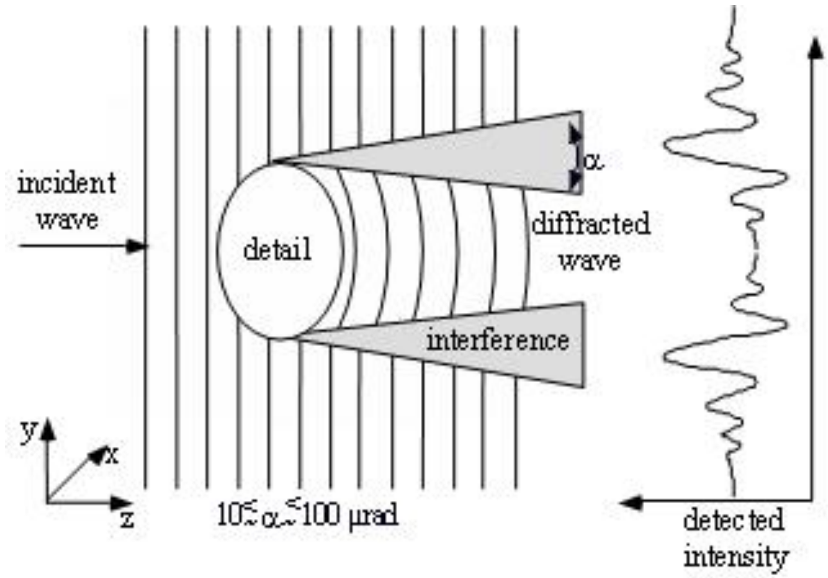
d and ß as a function of energy in keV for biological tissue

absorption vs phase contrast imaging

different contrast **generation**



absorption

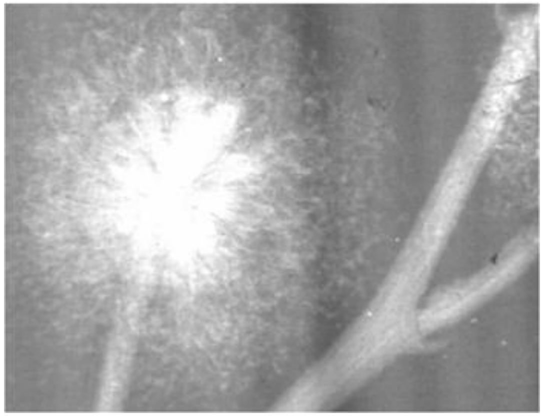


phase contrast

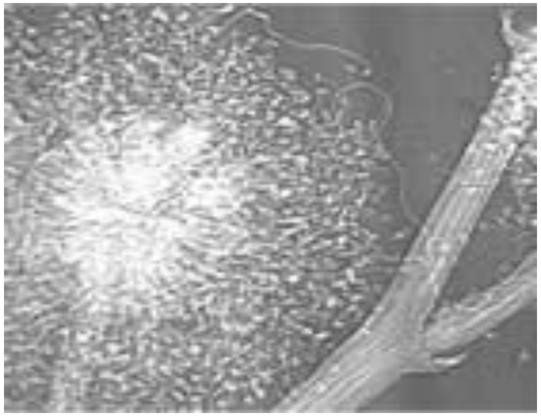
http://www.medphys.ucl.ac.uk/research/acadradphys/researchactivities/pci.htm

absorption vs phase contrast imaging

different contrast **quality**



absorption

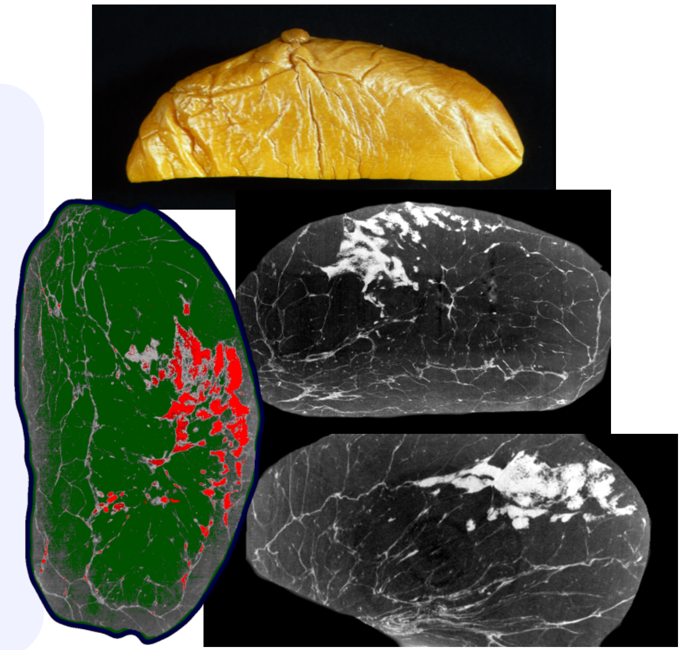


phase contrast

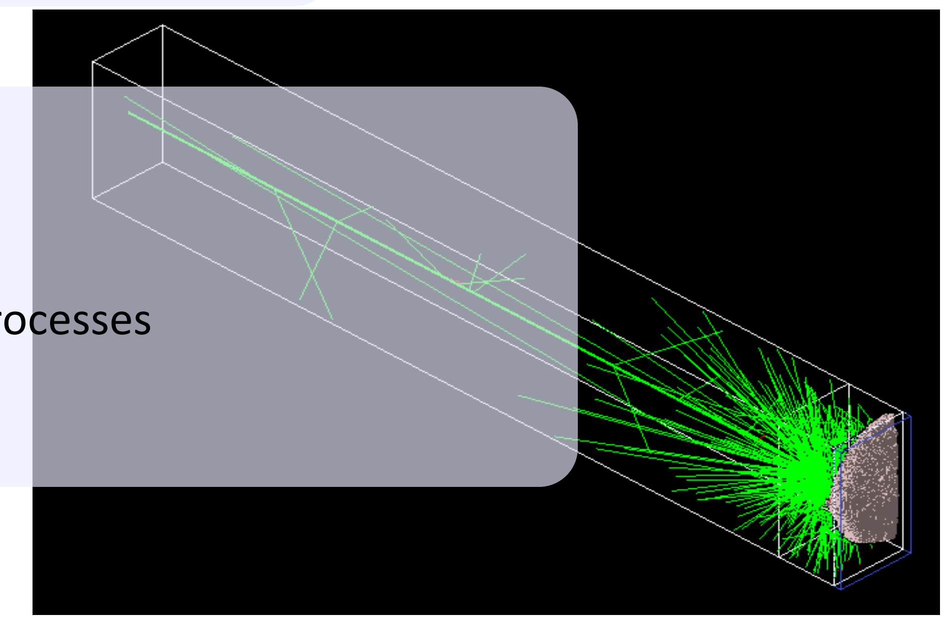
http://www.medphys.ucl.ac.uk/research/acadradphys/researchactivities/pci.htm

absorption imaging: simulations

- high resolution voxel models of breast
- created from CT-scans
  of anatomical breast specimens
- voxel size: 60 x 60 x 60 μm^3
- segmentation in different tissues:
  - adipose
  - glandular
  - skin

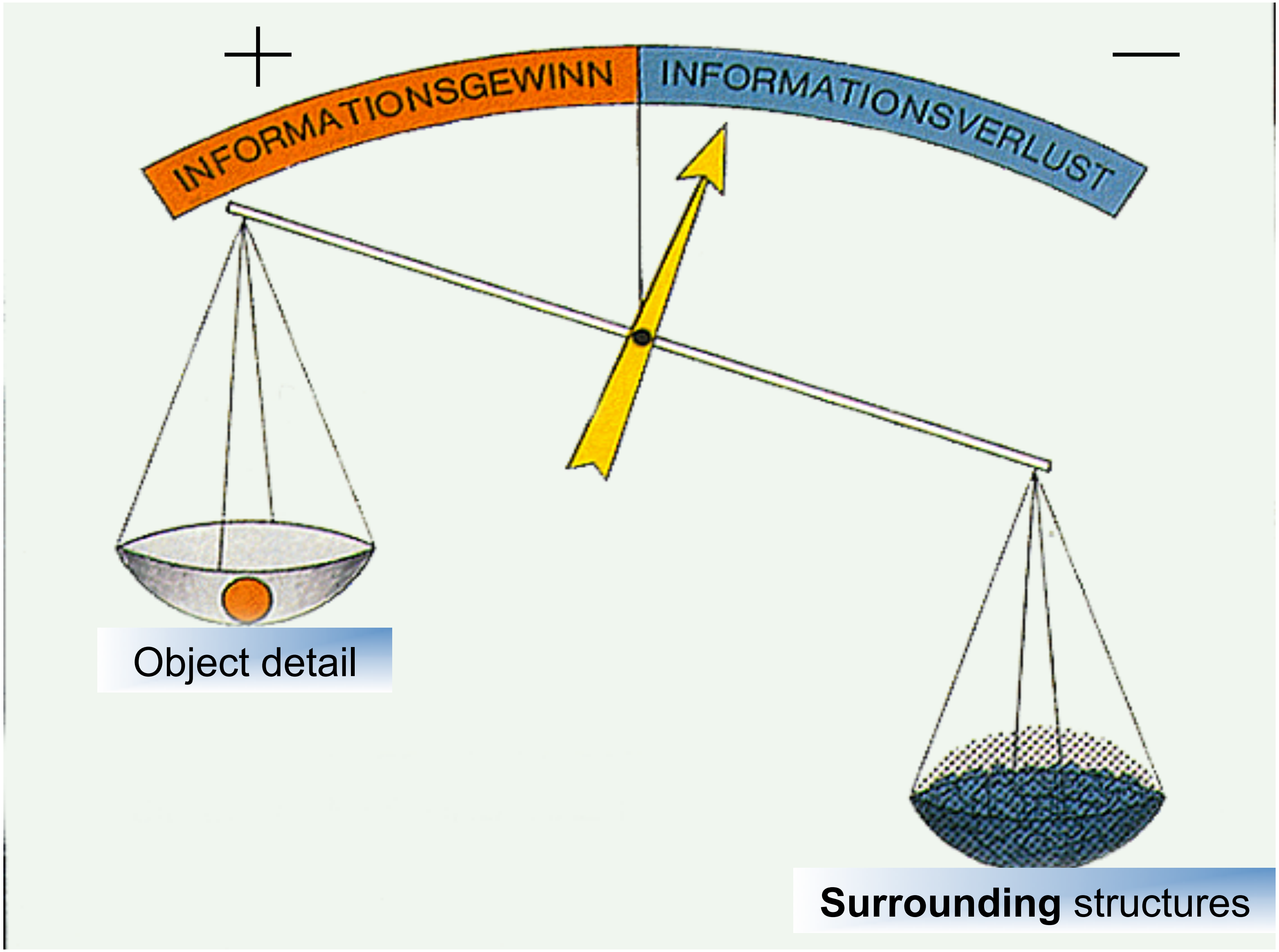


- using brilliant undulator radiation:
  beam geometry, spectral angular flux,...
- simulation of absorption and scattering processes
  with Geant4-Software-Toolkit



absorption imaging: contrast reduction

Balance in imaging processing

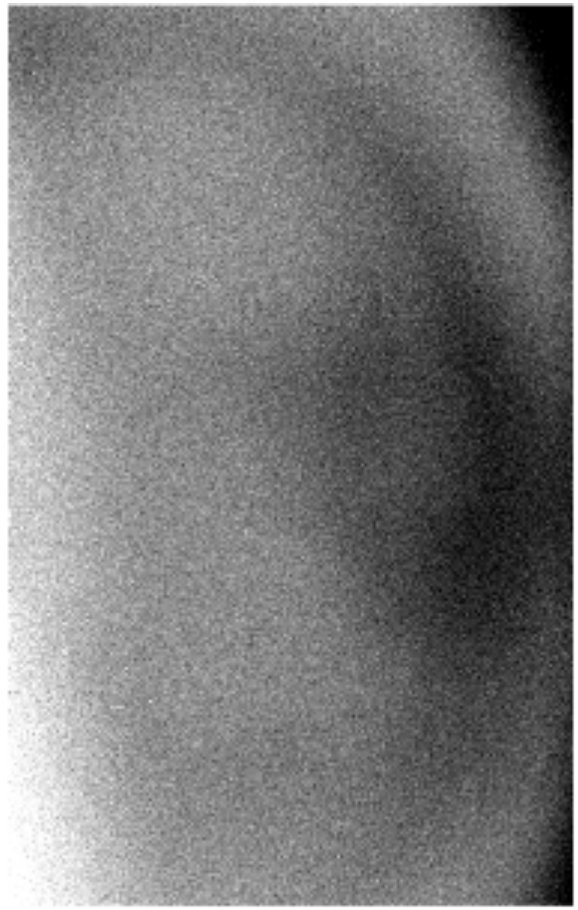


absorption imaging: contrast reduction

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

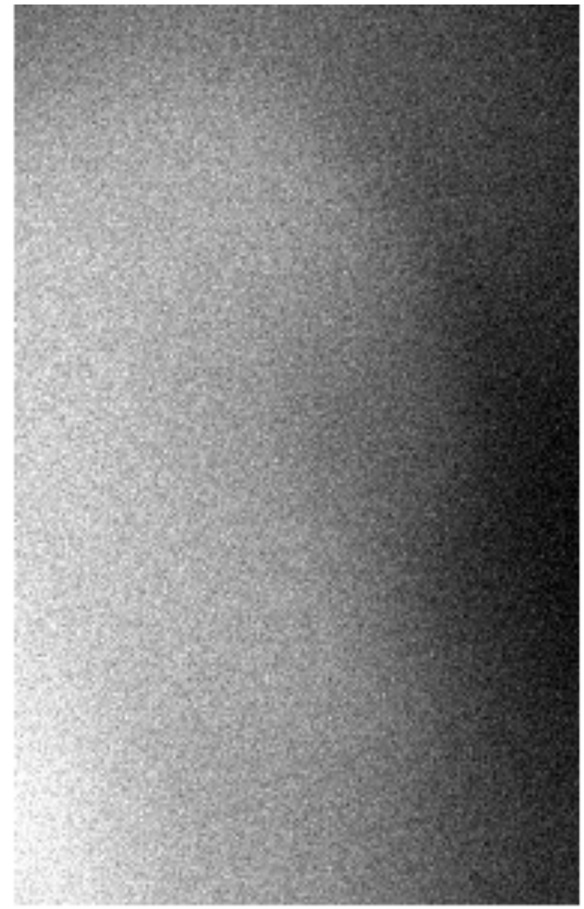
(a)

primary



(b)

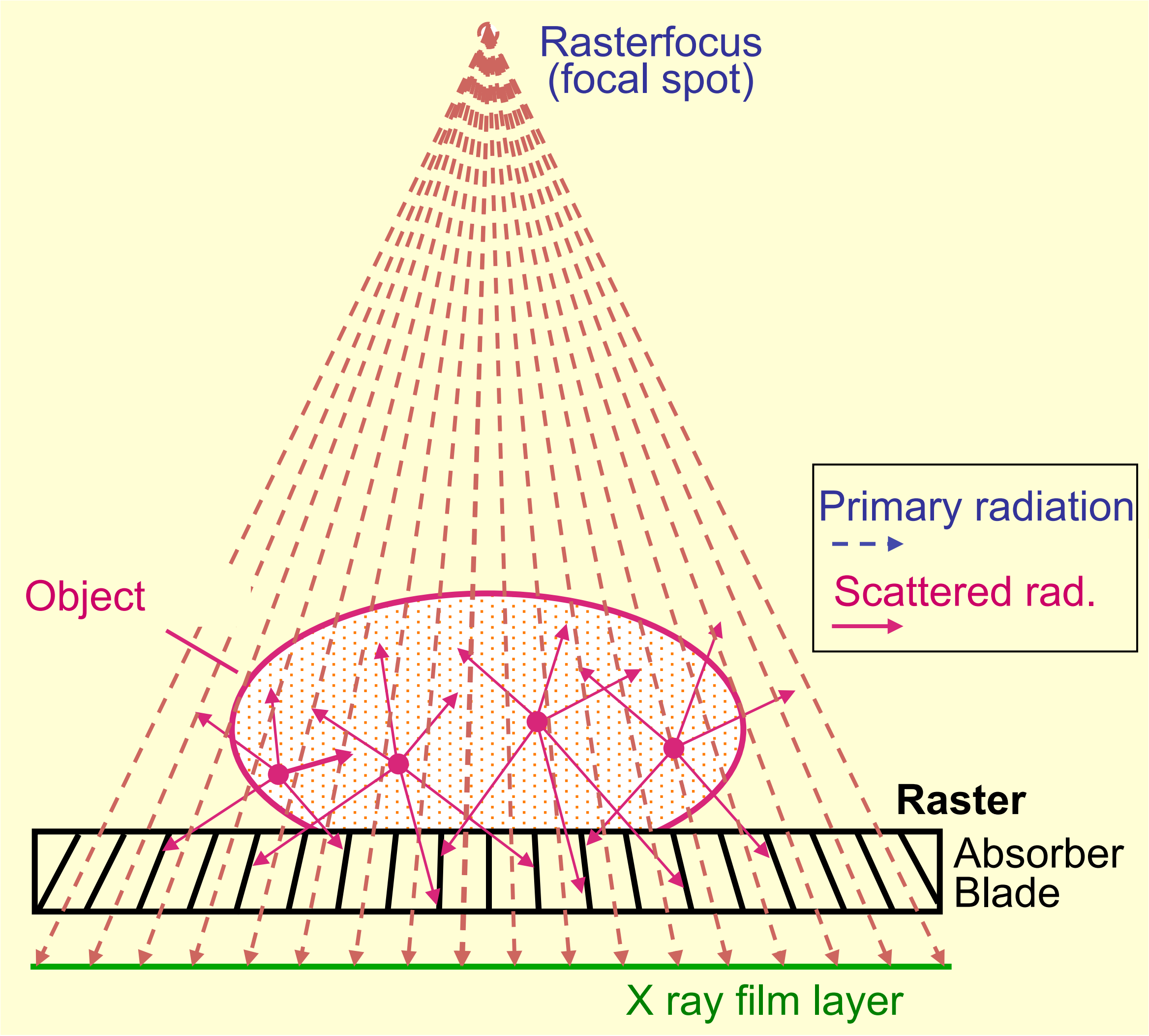
Rayleigh



(c)

Compton

absorption imaging: contrast enhancement



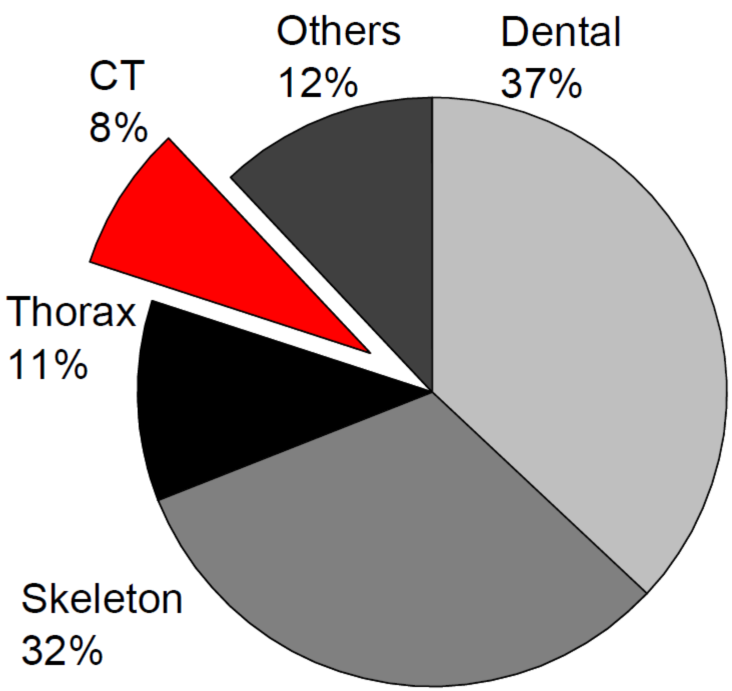
- geometrical limitation of radiation (aperture)
- anti-scatter grid

  ideal: focused anti-scatter grid

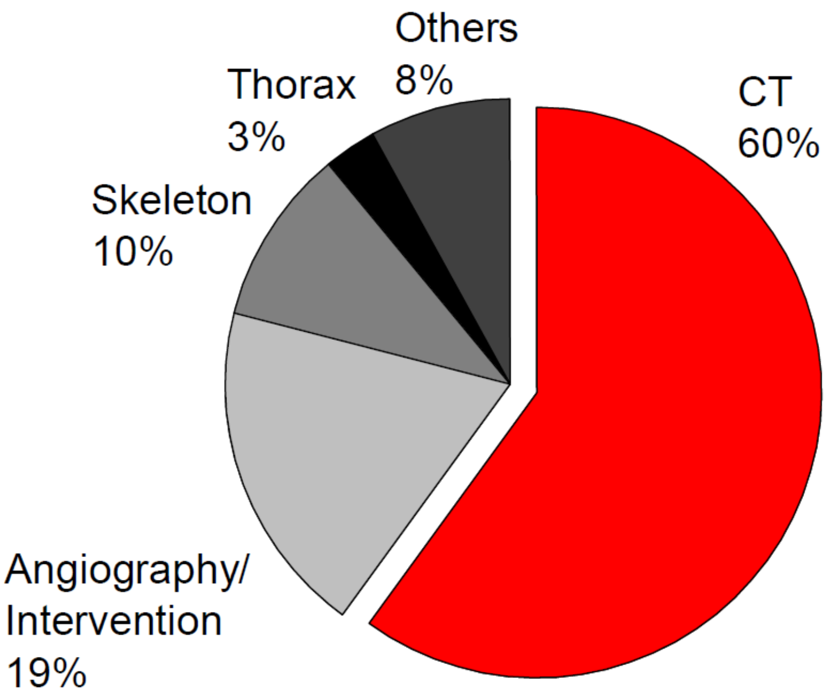
Anti-Scatter grid is placed directly on the film /screen-film-system / detector

absorption imaging: applied dose

a) Frequency of examinations

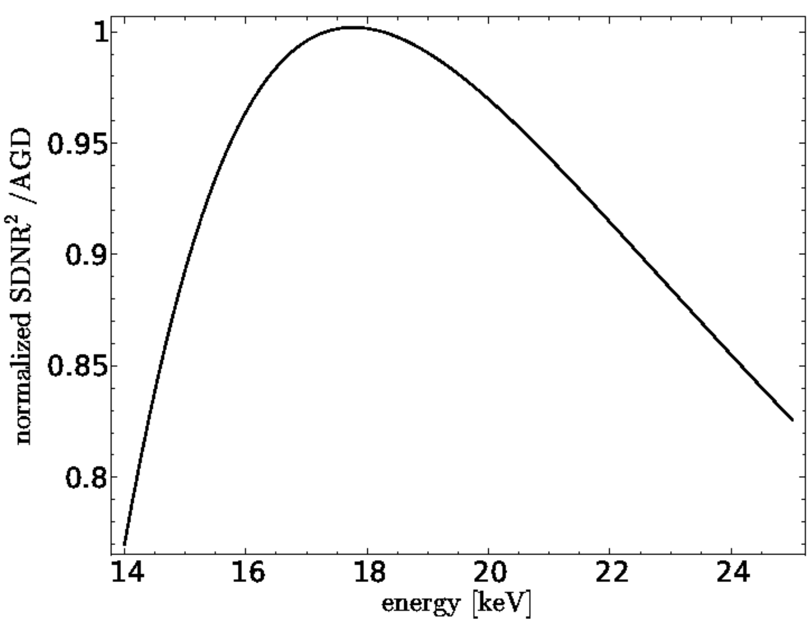


b) Collective effective dose from medicine

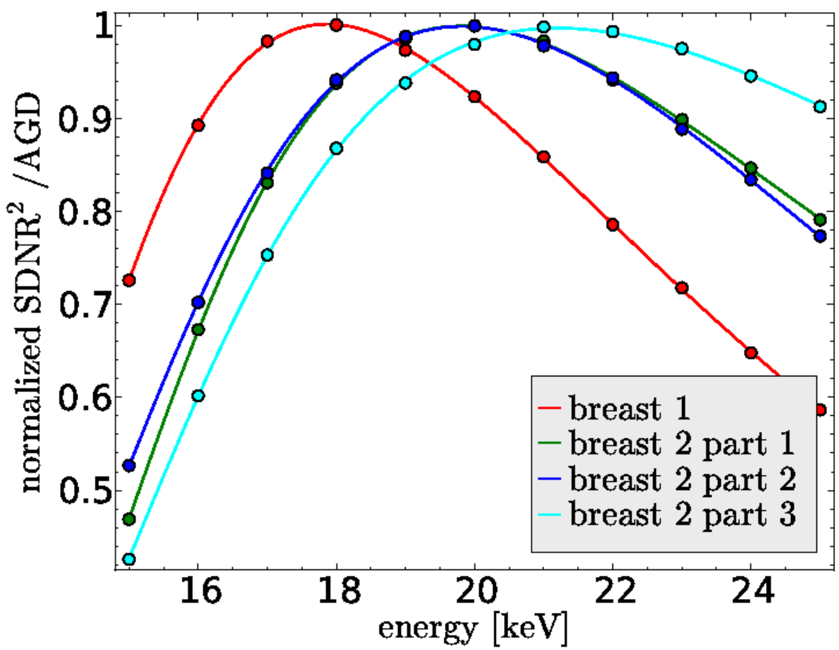


absorption imaging: applied dose

criterion = signal-difference-to-noise ratio versus averaged-glandular dose



analytical **model**

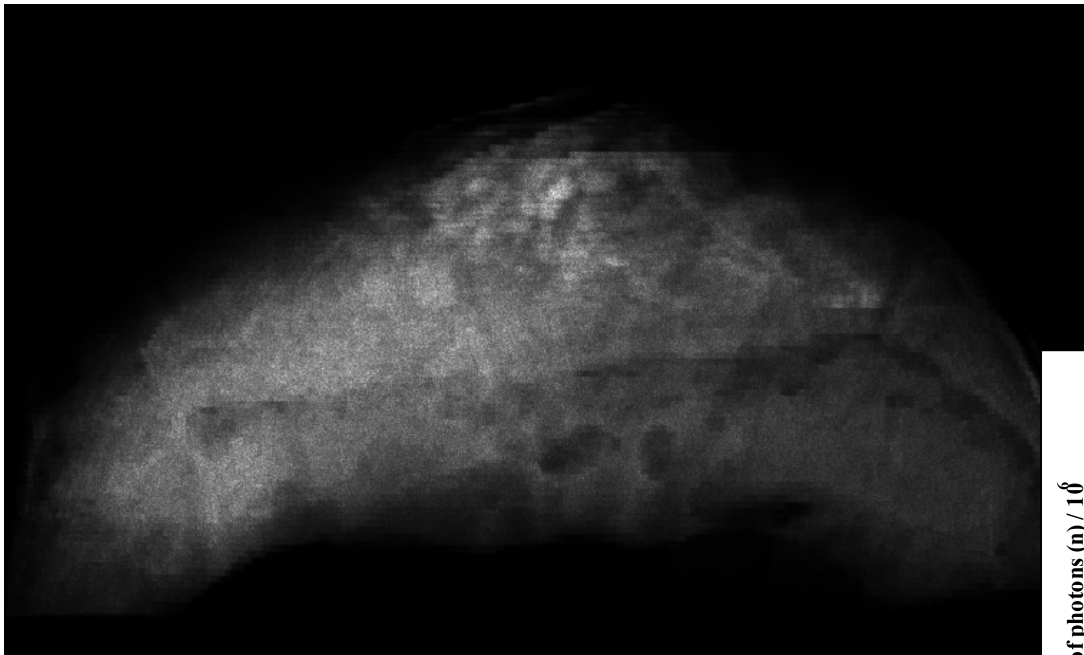


(b)

simulation for 3 different breast models

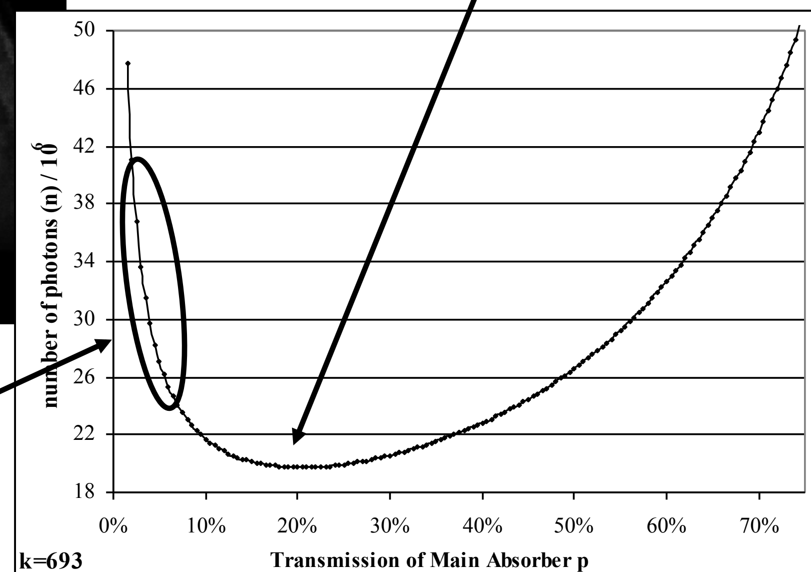
→ requires **tunable** source

absorption imaging: applied dose



Together with MAP-AG Florian Gruener

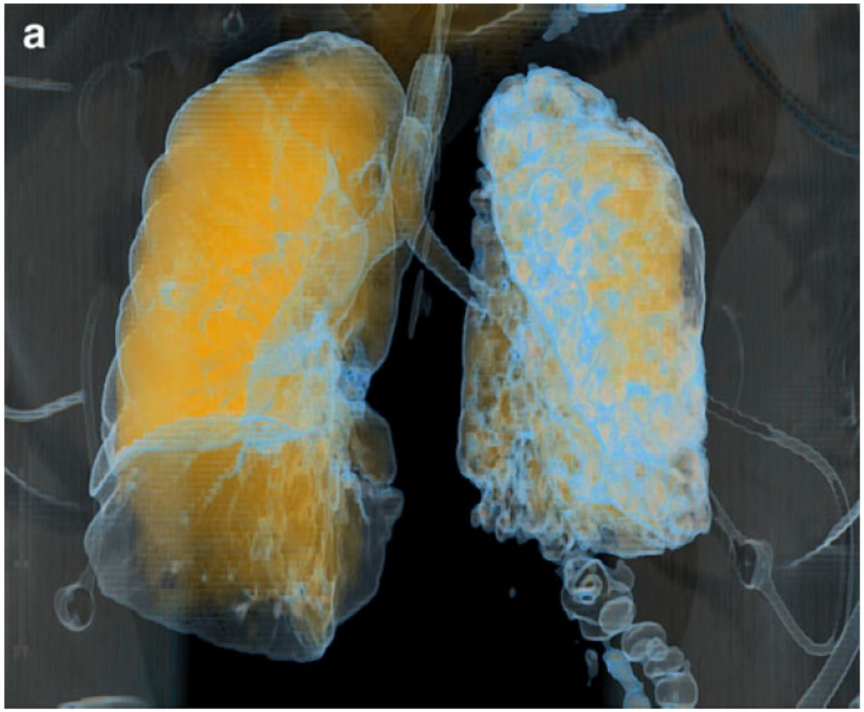
minimum is always at ca. 20% transmission through main absorber



Typically used number of photons in clinical systems

Together with Felix Schöfer, Schöfer et al. in prep.

dual energy



Lung perfusion dual energy CT, courtesy of LMU

Actual: dual energy CT with **contrast** media for e.g. lung perfusion

➔ New diagnostic tool

➔ at least two scans

➔ high dose

➔ registration problems

➔ non-optimal image information due to overlapping spectra

➔Limitations for suitable markers

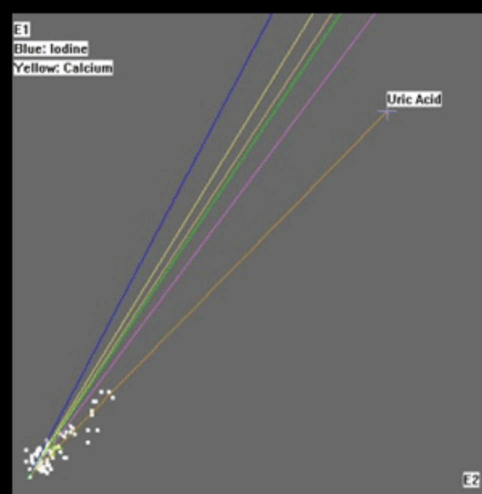
With especially designed „monoenergetic“ radiation low dose individualised medicine will be developed together with MAP II

dual energy

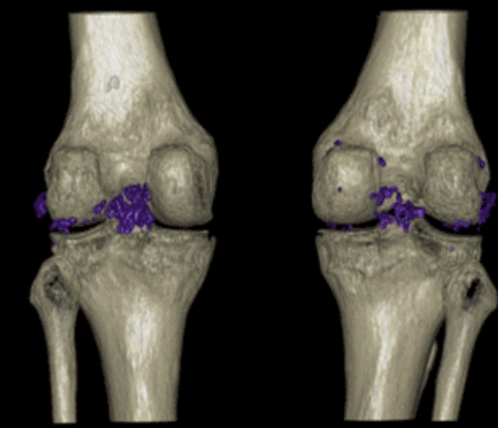
Brilliance iCT

Dual Energy

- A sampling of dual energy scans demonstrating clinical application to:
  - gout detection and quantification
  - kidney stone characterization
  - tendon/ligament differentiation.



Renal Stone Analysis



Gout Visualization

Tendon/Ligament Visualization

coherent scatter imaging

- - Differentiation between tissue structures
- most notably between **malign** and **benign** carcinomas by
  - different scatter intensity caused by change in the collagen structure of malign tissue
  - different scatter distribution

➔ **Differentiation between malign and benign tissue without the need for biopsy would be a great benefit**

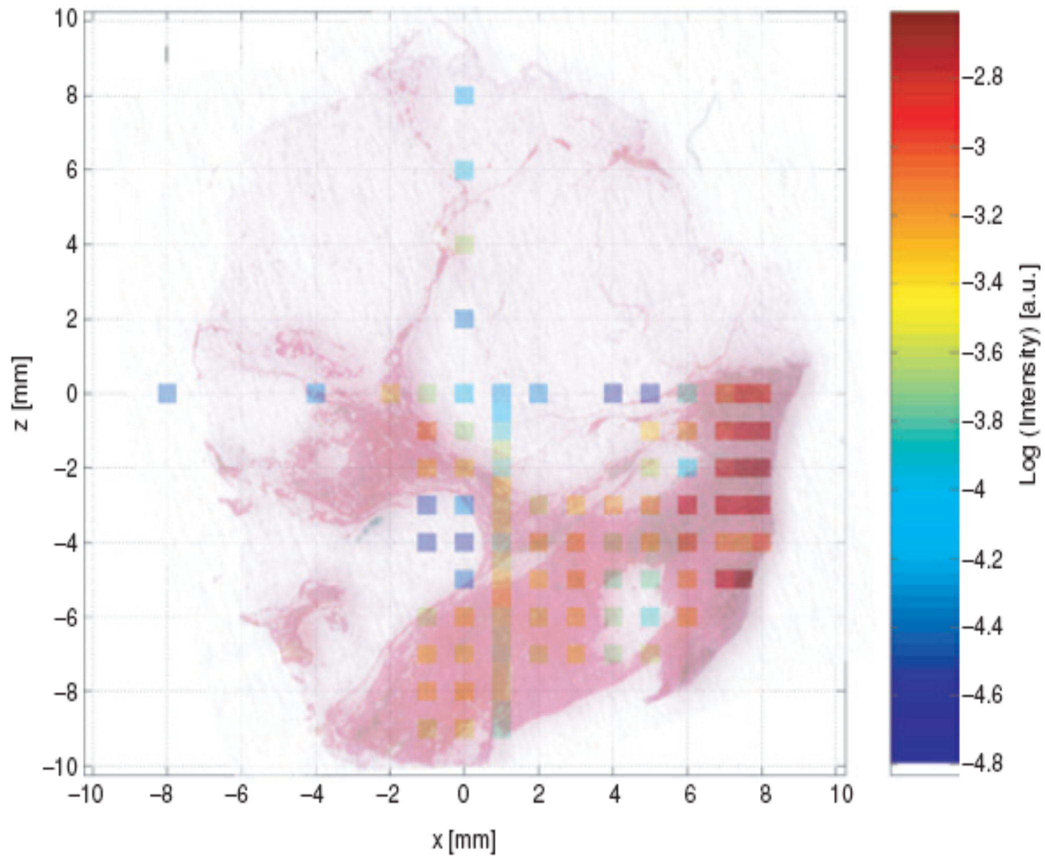
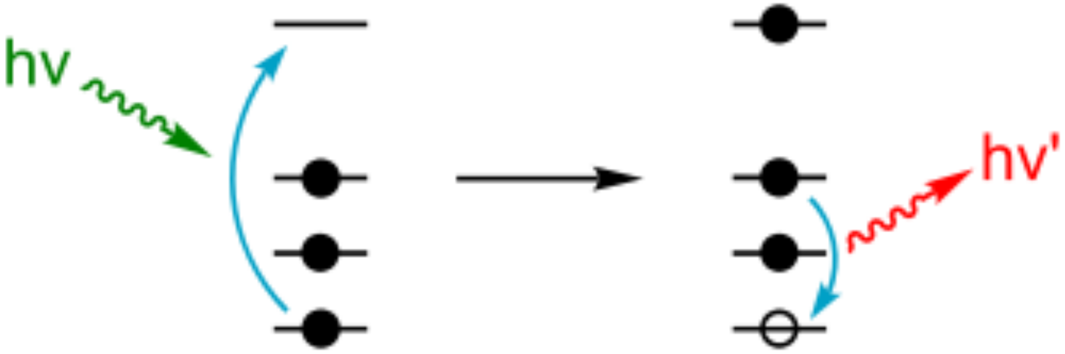
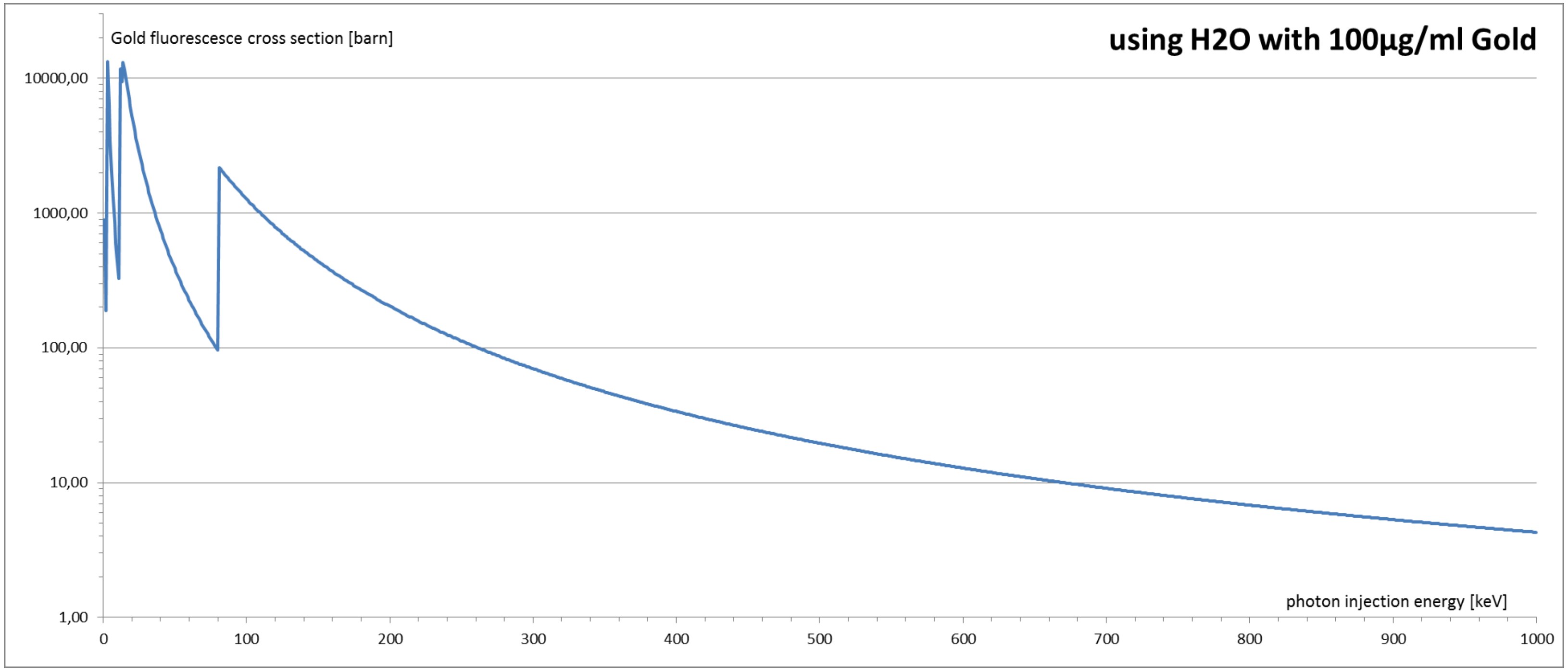


Image of scatter distribution in tumour

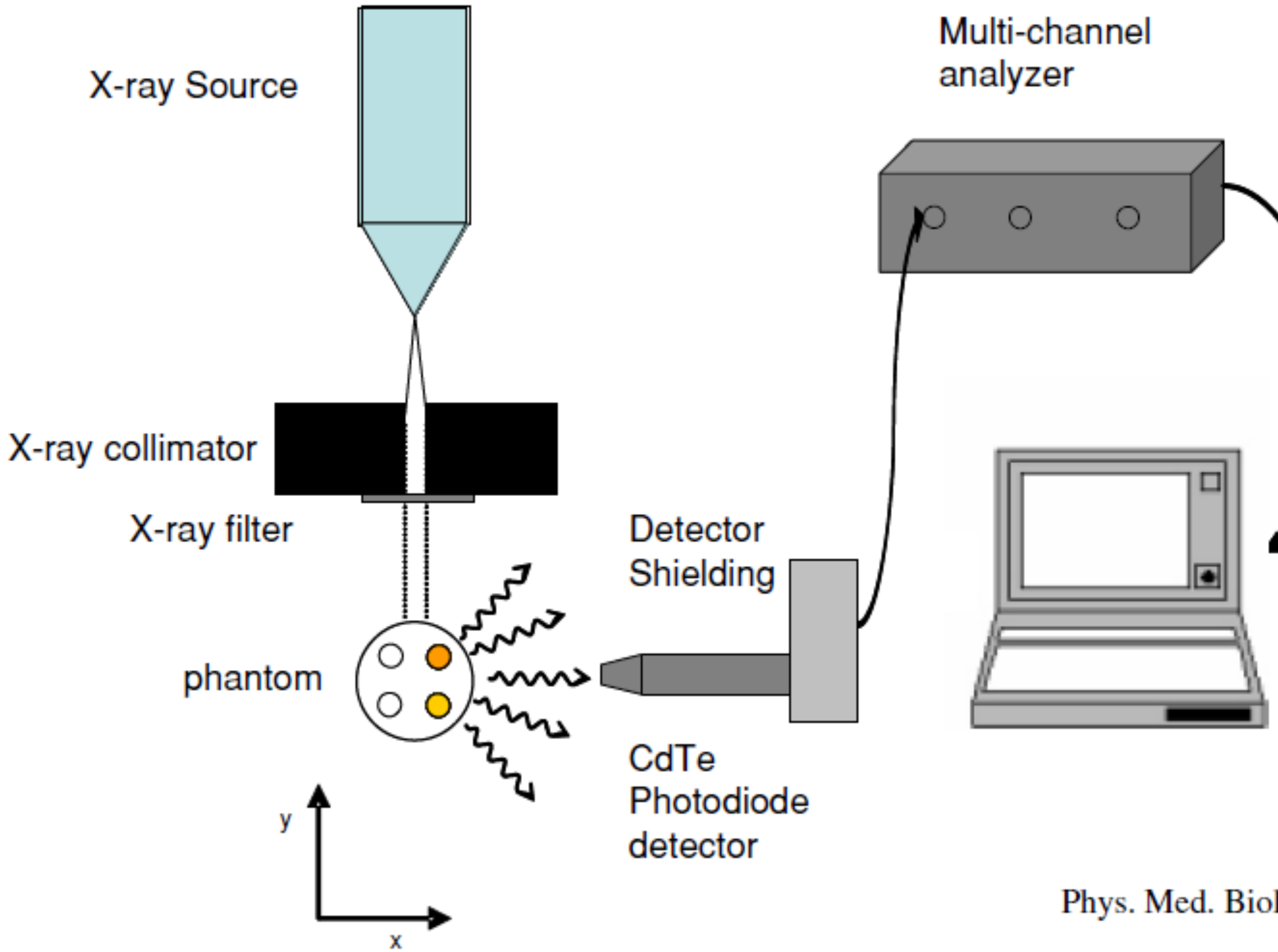
X-ray fluorescence imaging



e.g. 100 keV incident,
69 keV Au line

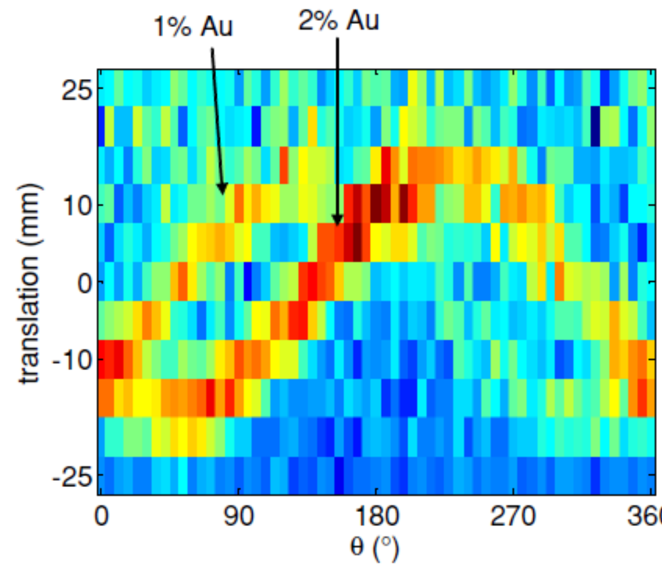


fluorescence imaging: experiments



Phys. Med. Biol. 55 (2010) 647–662

fluorescence imaging: experiments



sinogram

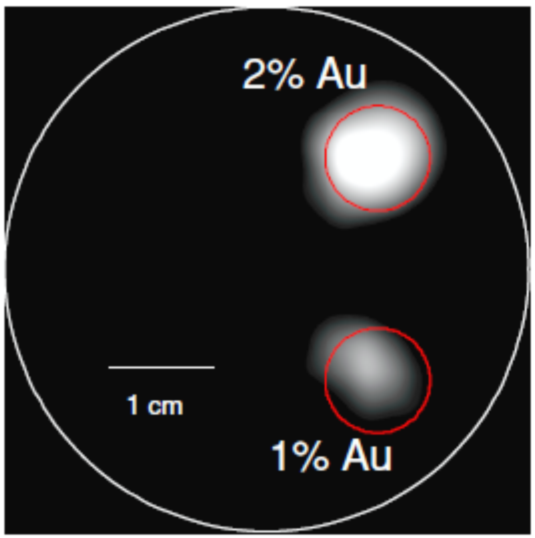


Figure 8. Reconstructed GNP distribution and location within the PMMA phantom using experimental data shown in figure 7.

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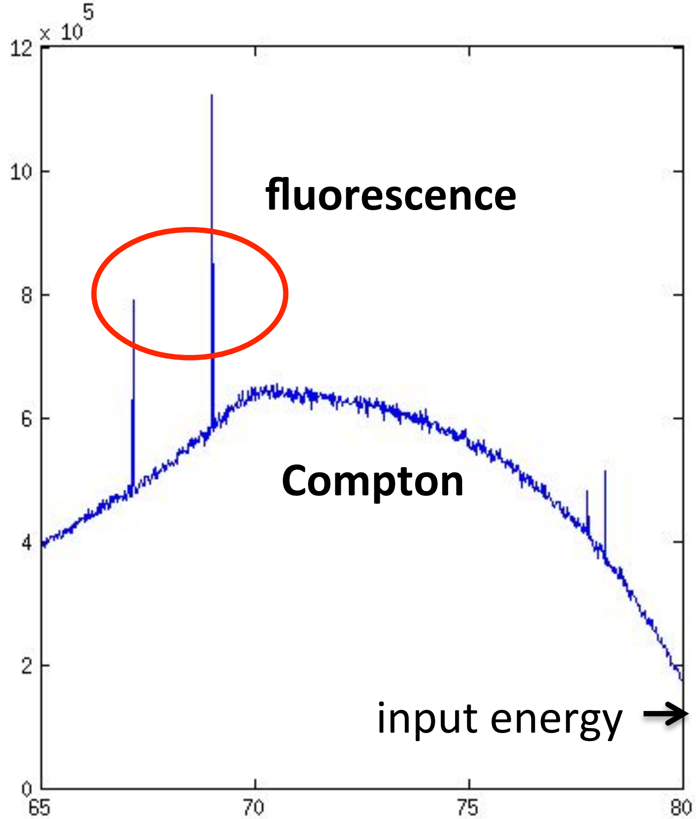
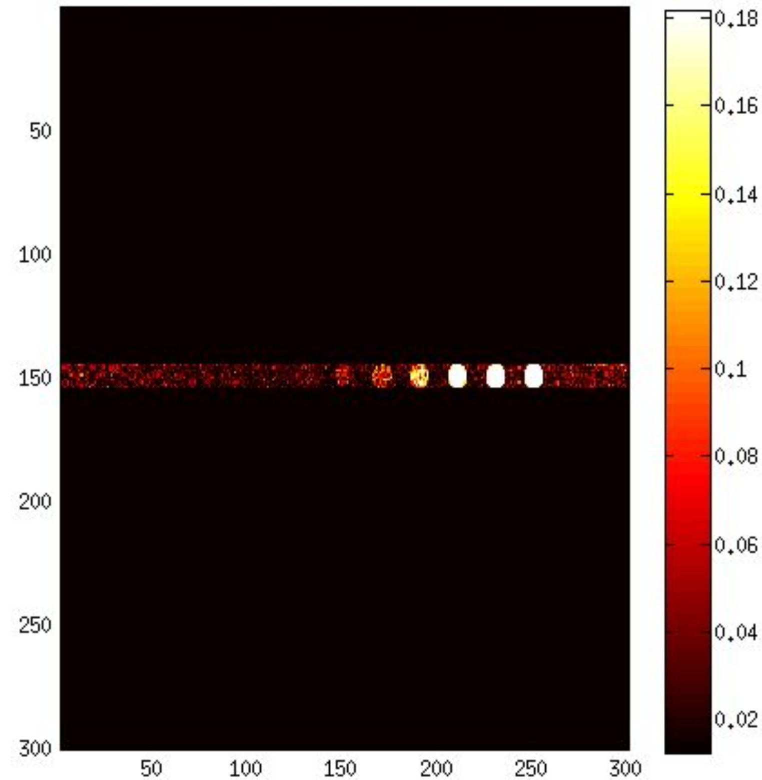
fluorescence imaging: background





max. sensitivity at 1mGy / 5mm pixel / CNR=5 ~ **10µg/ml**
~ **100 times** more sensitive than transmission-CT

(simulation by B. Müller, HZM/MAP)

Physicists' impacts

- new **methods**:
    - phase-contrast with low-brillance sources
    - absorption/x-ray fluorescence with high-brillance sources
- pushing the **limits**:
    - dose reduction
    - lowering the concentration of contrast media
    - enhancing the sensitivity
    - enforcing persoanlized medicine
- **cooperations** between medicine and physics:
    - possibly comparative studies between UKE and my group (magnetic particle imaging vs X-ray fluorescence imaging
    - new detectors for medicine (Erika!!)