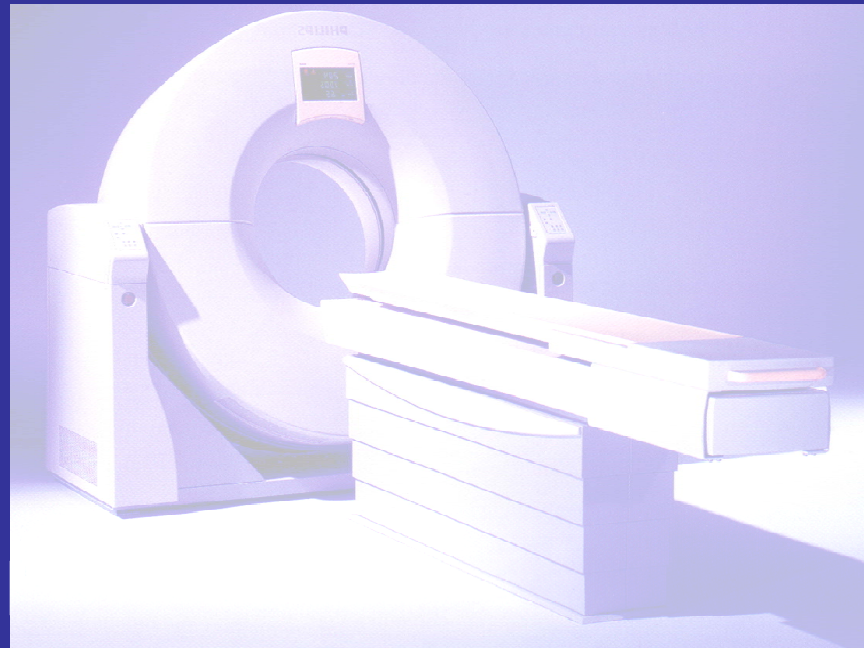
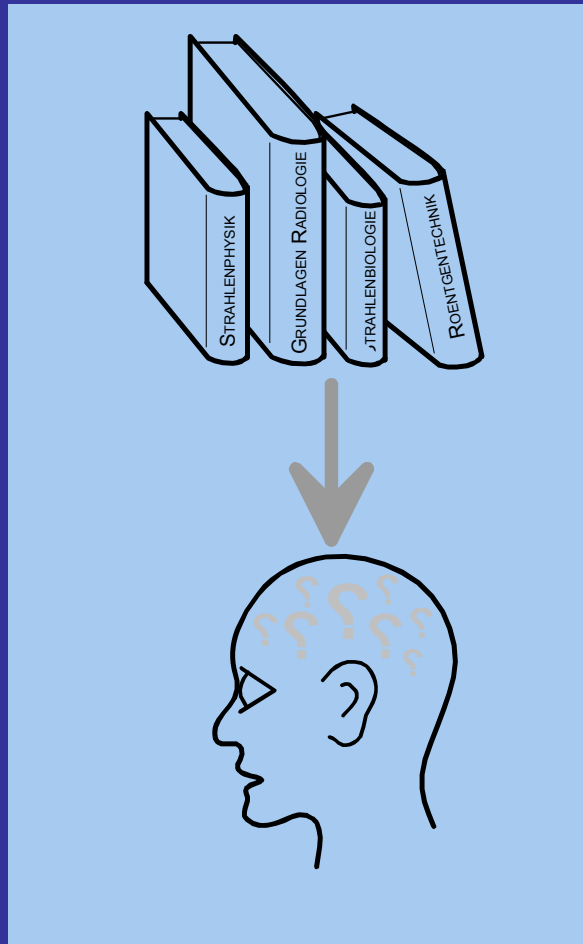


Grundlagen der Computertomographie



Dr. Stephan Scheidegger, 2006

Computertomographie



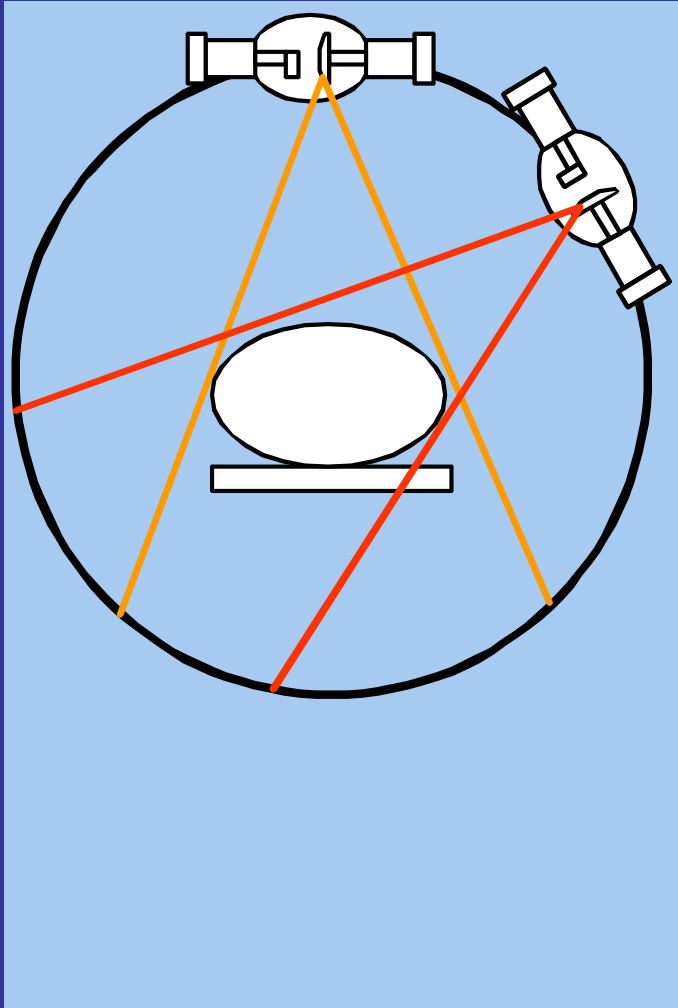
Inhalt

Technik der Computertomographie

- Bild-Rekonstruktion
- Scanning-Methoden

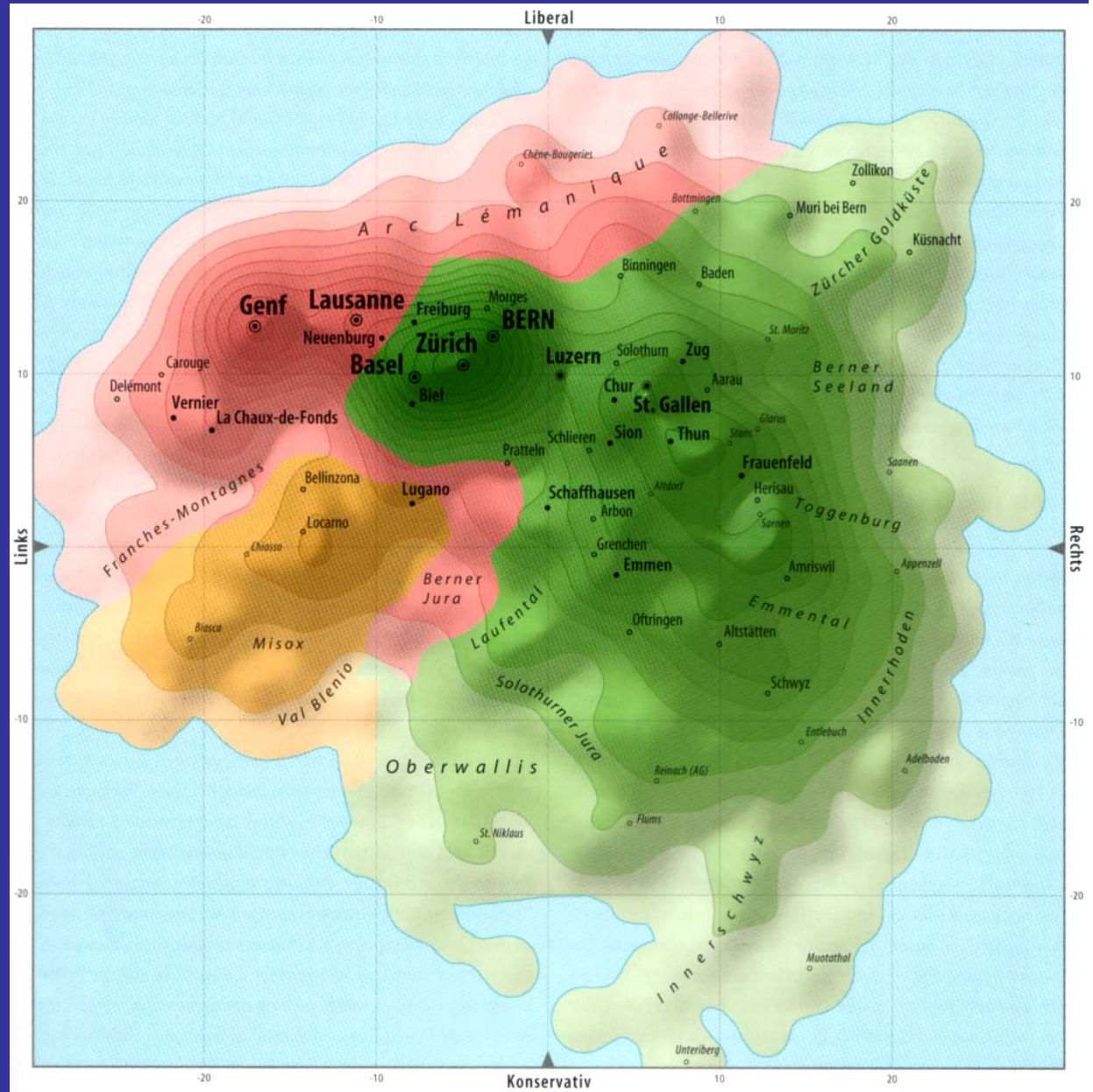
Dentale Volumentomographie

Computertomographie

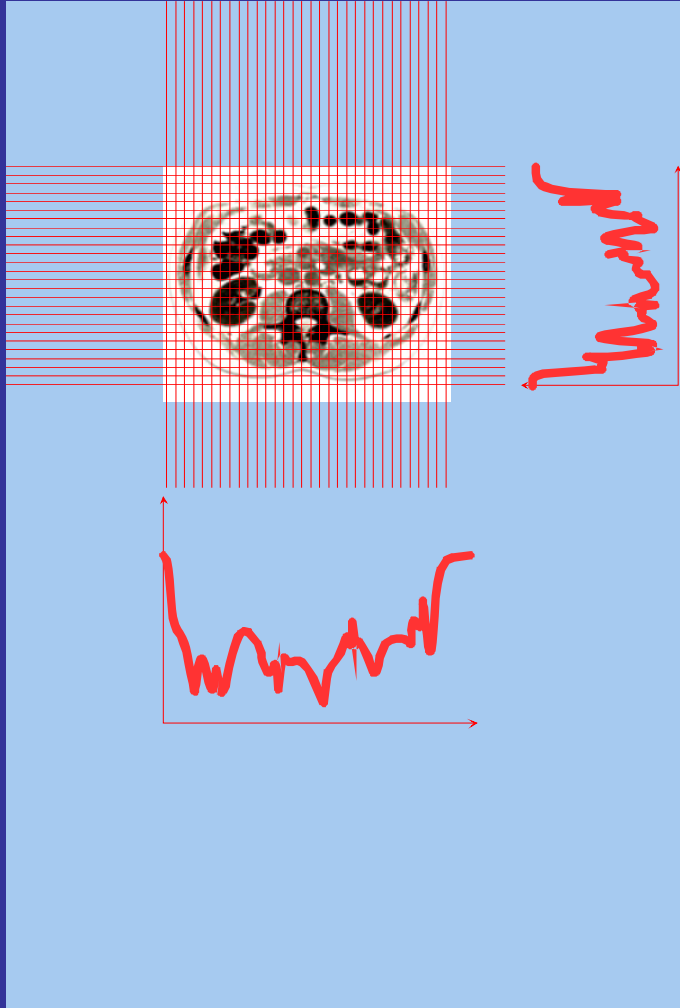


Schnittbildverfahren

- CT, MRI
- PET, SPECT
- Sonographie



Computertomographie



Schnittbildverfahren

- Messdaten: Projektionen
- Rekonstruktion: 2-Dim. Bild aus 1-Dim. Projektionen

Computertomographie

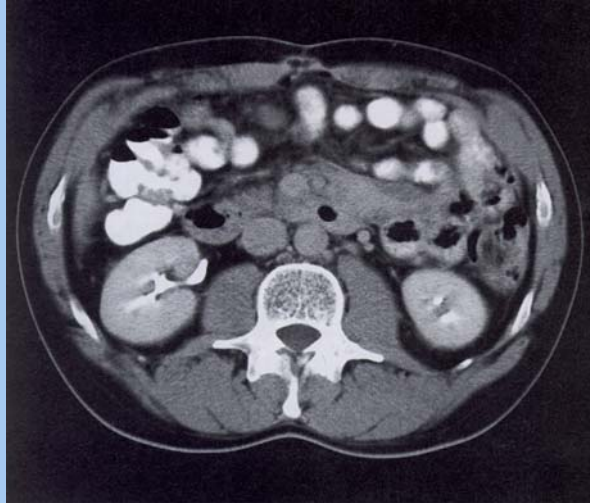


Bild-Rekonstruktion

- Ideales Bild ist unendlich scharf (unendlich viele Projektionen erforderlich)
- Reales Bild besteht aus Pixel
(Volumentomographie: Voxel)

Computertomographie

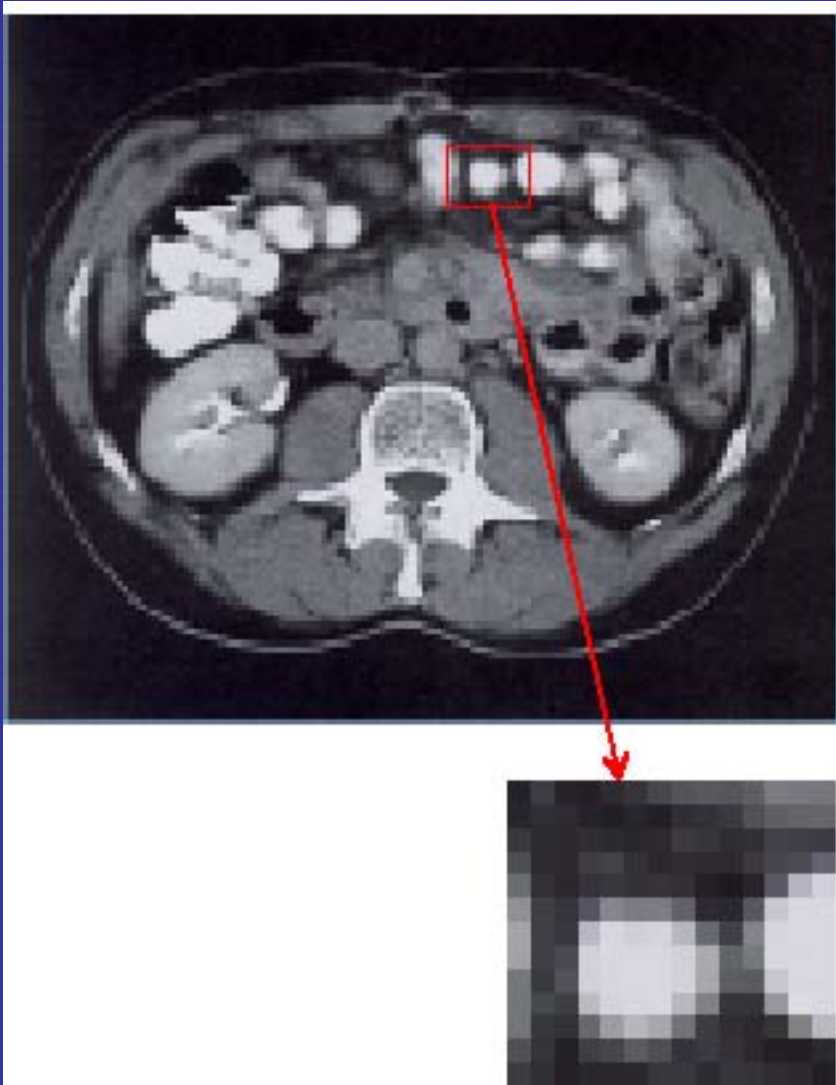


Bild-Rekonstruktion

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- Reales Bild besteht aus Pixel
(Volumentomographie: Voxel)

Computertomographie

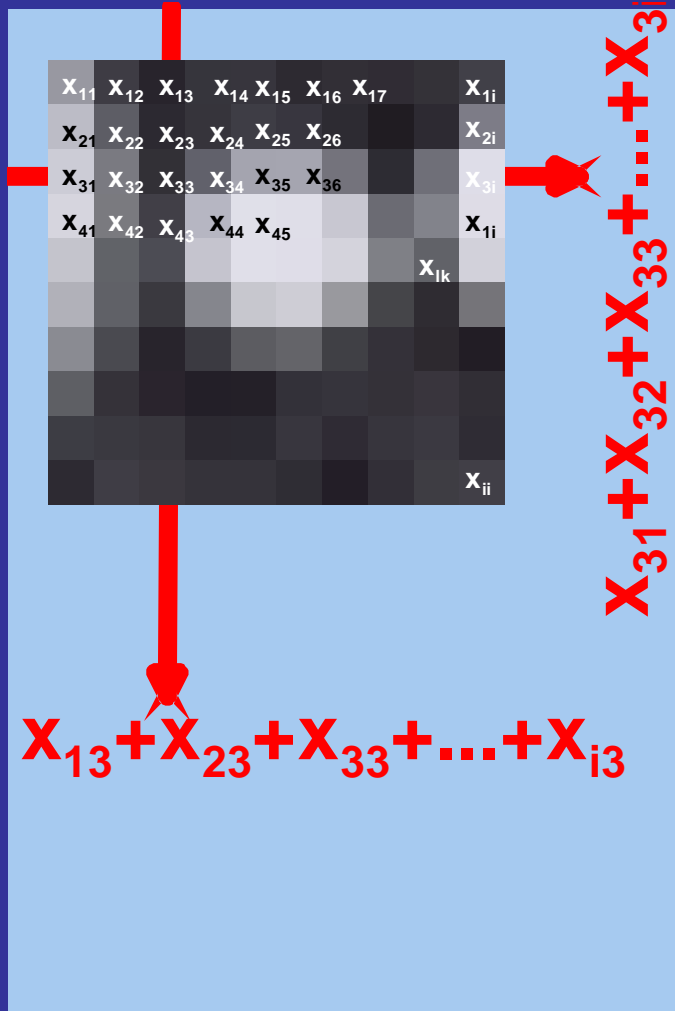


Bild-Rekonstruktion

- Projektion: entlang Strahl ändert Absorption
- Pro Pixel ein best. Absorptionswert
- Schwächung des Strahls: Summe aller Beiträge

Computertomographie

$$I = I_0 e^{-\int ds \cdot \mu(x, y)}$$
$$\Rightarrow P(\varphi) = \ln\left(\frac{I_0}{I}\right)$$
$$= \int_s ds \cdot \mu(x, y)$$
$$\approx \sum_i \mu_{ik}$$

Bild-Rekonstruktion

- Schwächung des Strahls:
Beer-Lambertsches Gesetz

Computertomographie

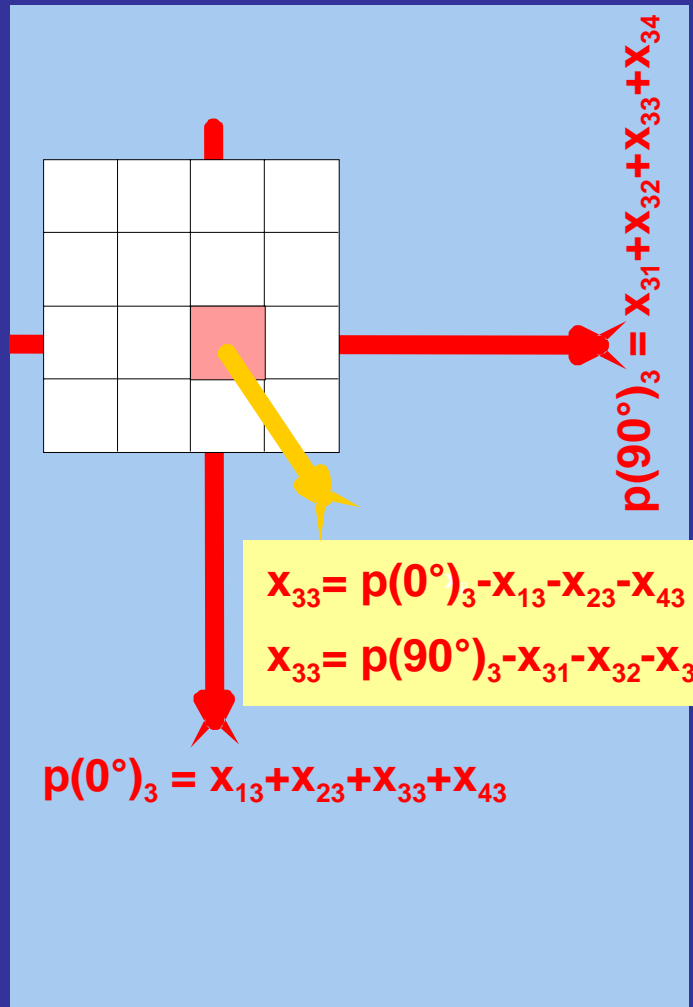
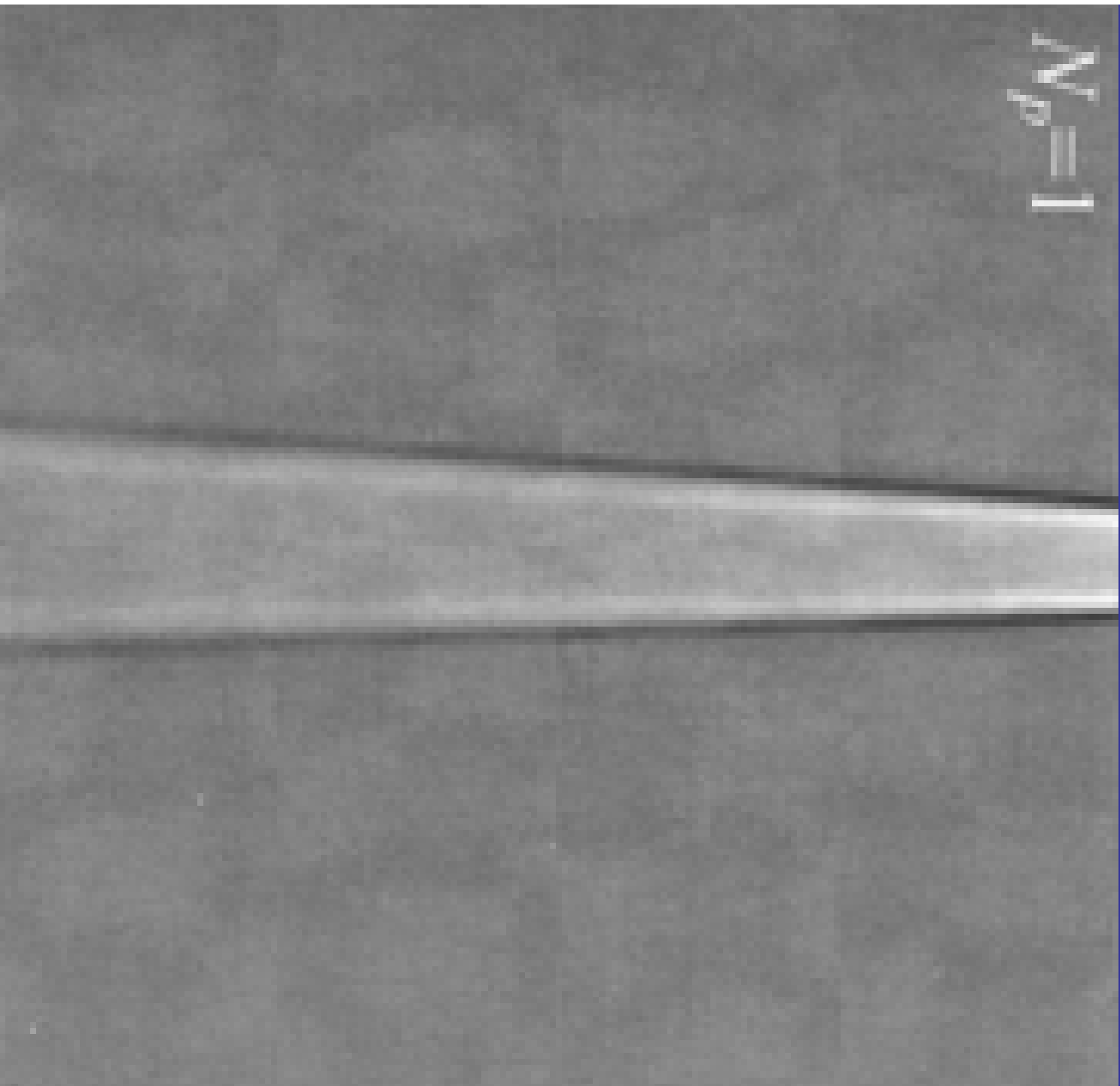


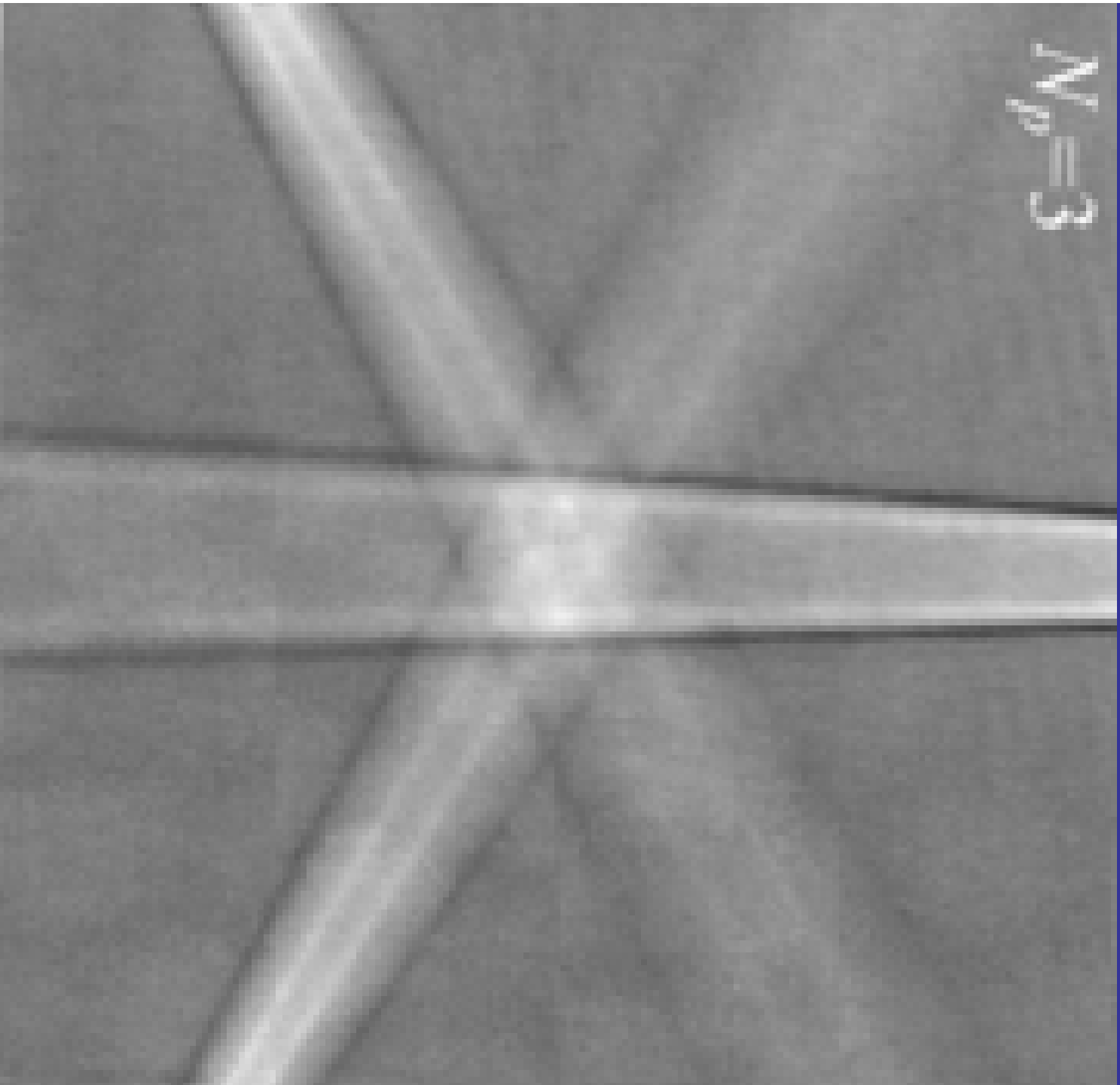
Bild-Rekonstruktion

- Pro Strahl (Kolonne, Zeile) eine Gleichung
- Alle Strahlen bilden ein Gleichungssystem
- Auflösung möglich für Anz. Gleichungen = Anz. Unbekannte

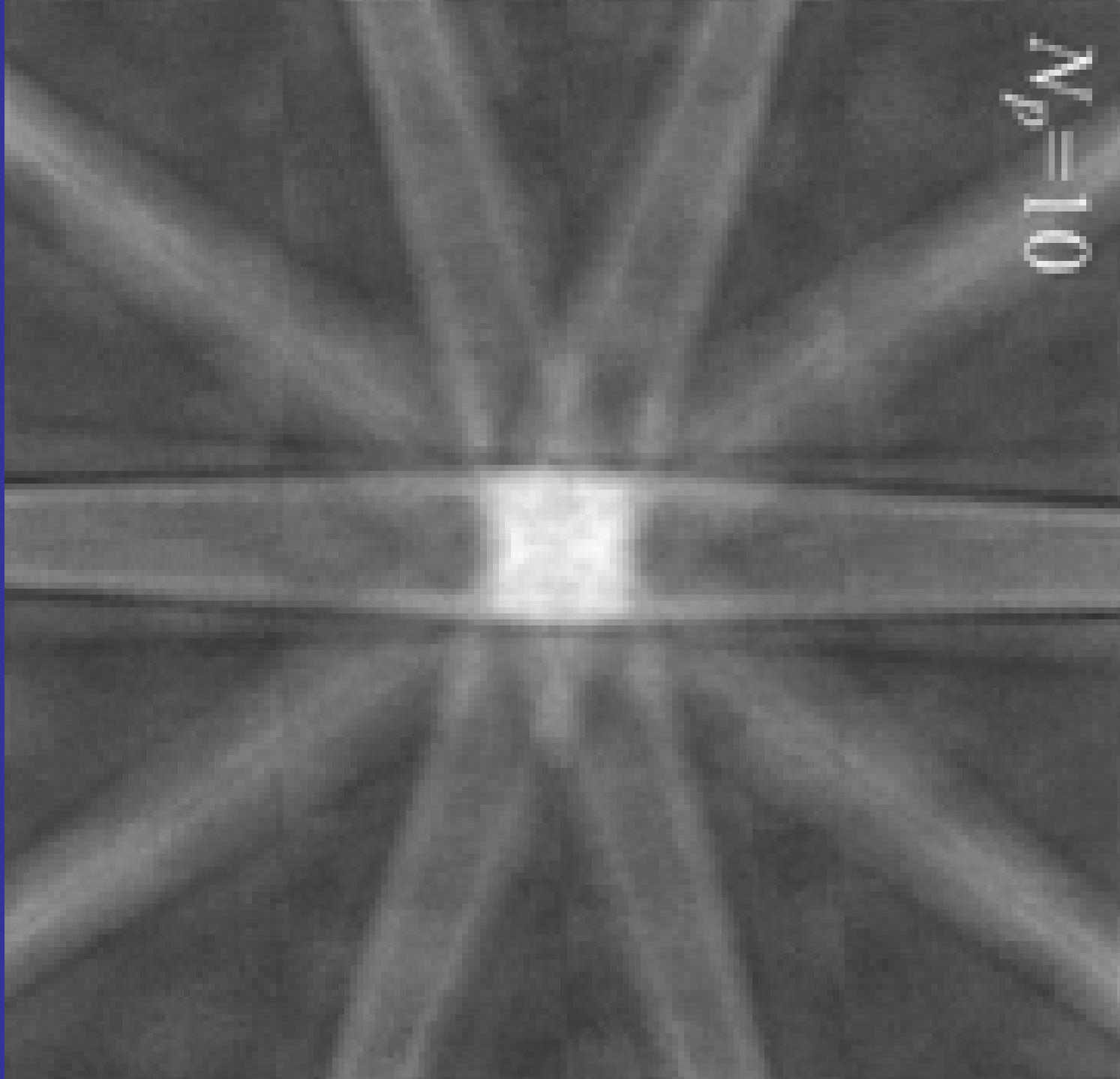
$$N/p = 1$$



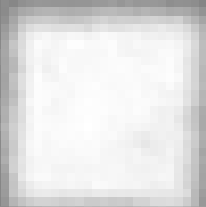
$N/p = 3$



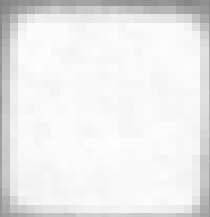
$$M_p = 10$$



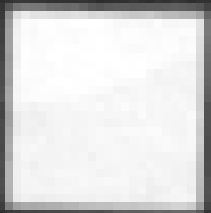
$N/p = 25$



$$\gamma_{p'} = 100$$



$$N/p = 180$$



1

Computertomographie

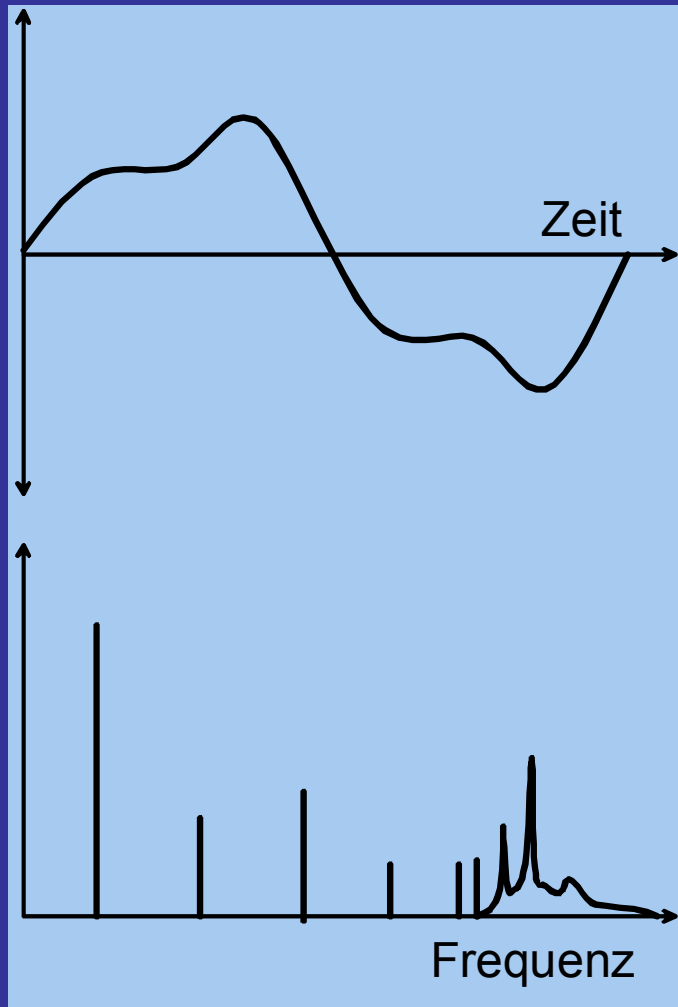
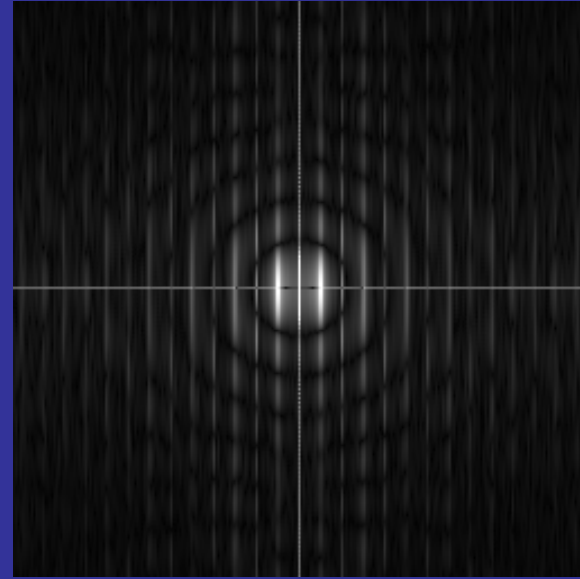
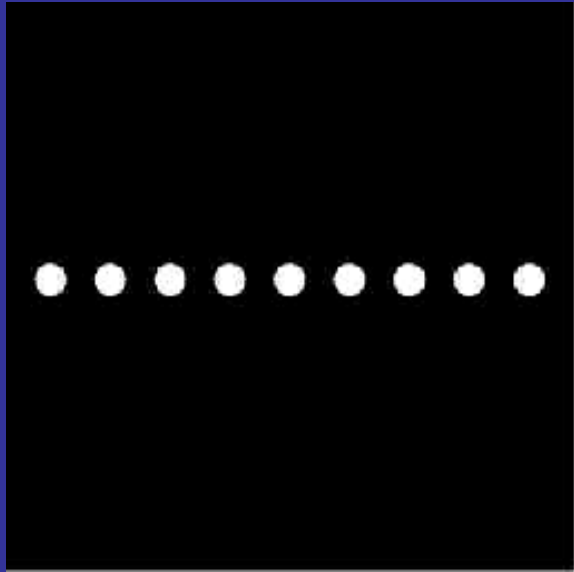
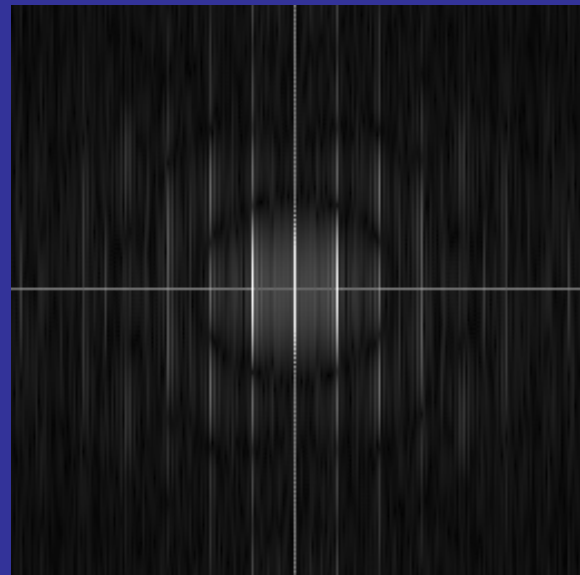
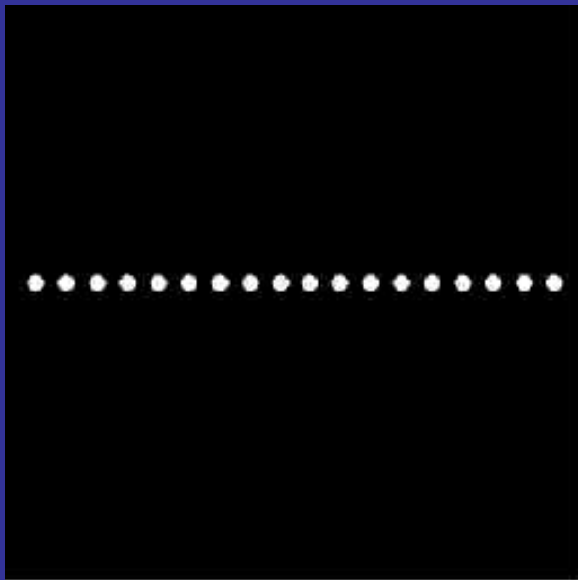


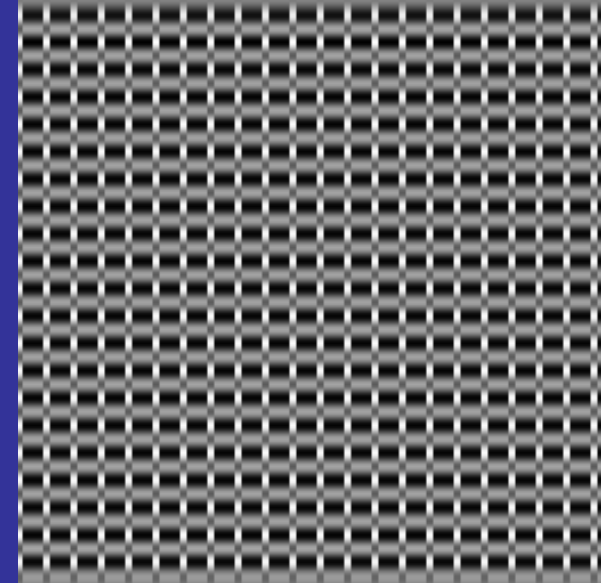
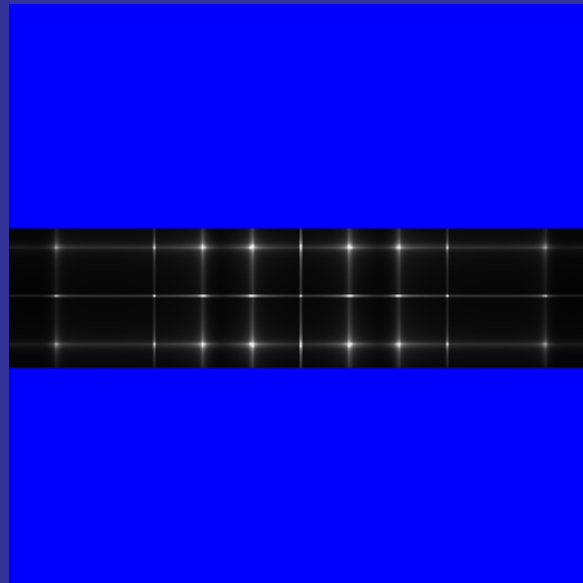
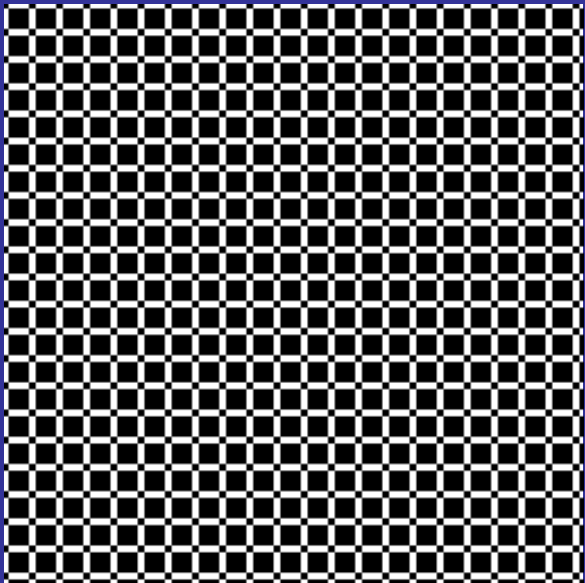
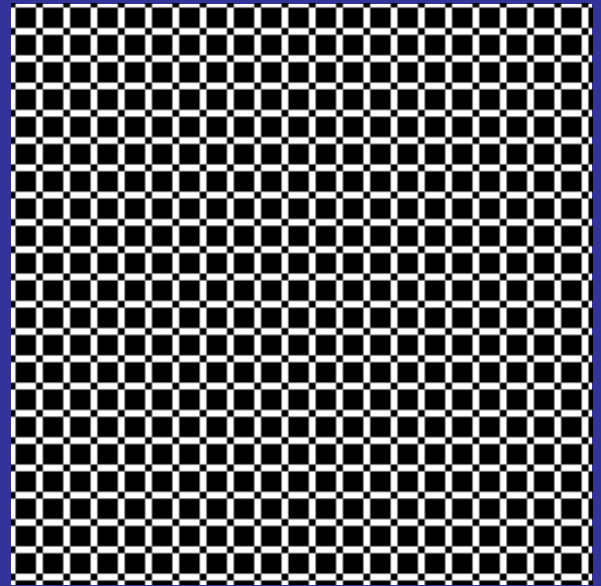
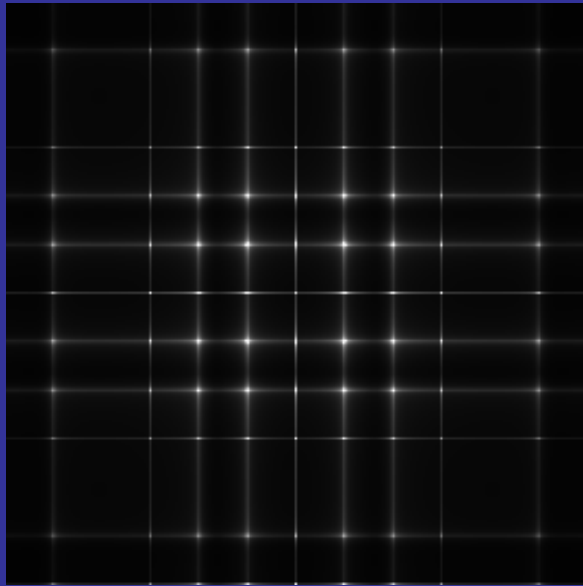
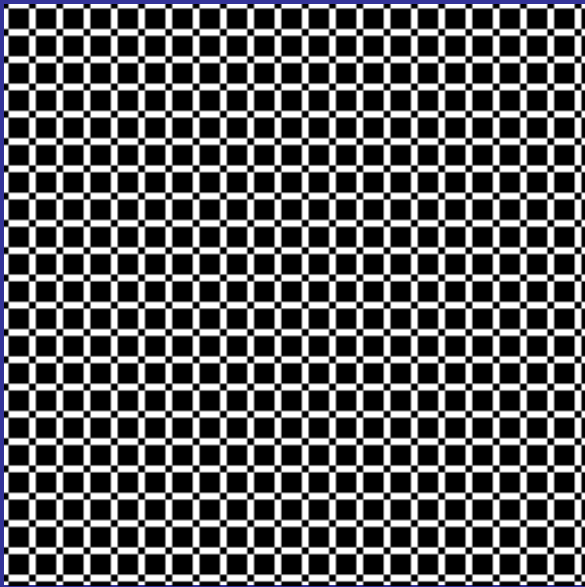
Bild-Rekonstruktion

- Elegantere Variante: Fourier-Transformation
- Pendel: Auslenkung-Zeit \rightarrow Amplitude-Frequenz
- Analog Bild: Schwärzung-Ort \rightarrow Amplitude-Bildfrequenz



FT





Computertomographie

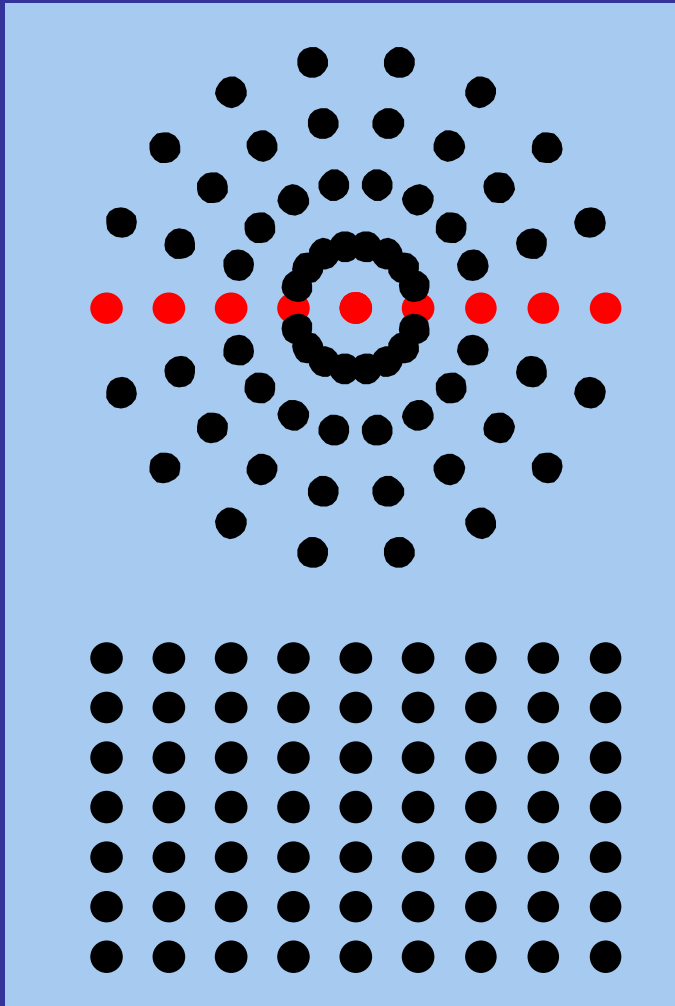
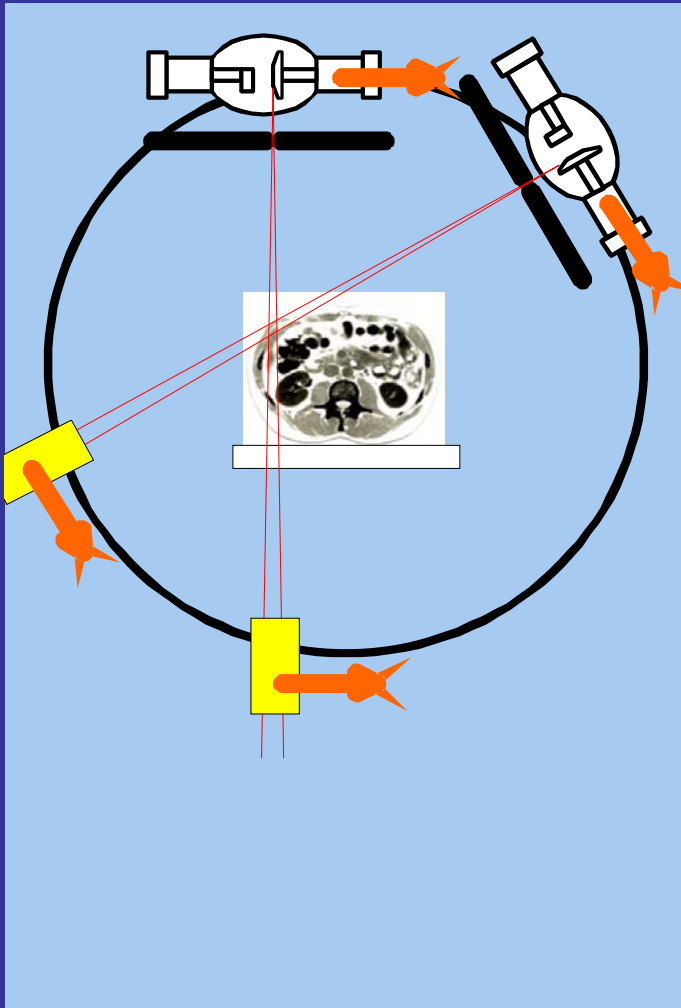


Bild-Rekonstruktion

- Projektionen \rightarrow Schnitte
- Messung von Projektionen
- FFT
- Zusammensetzung von Schnitten
- FFT^{-1} : Bild

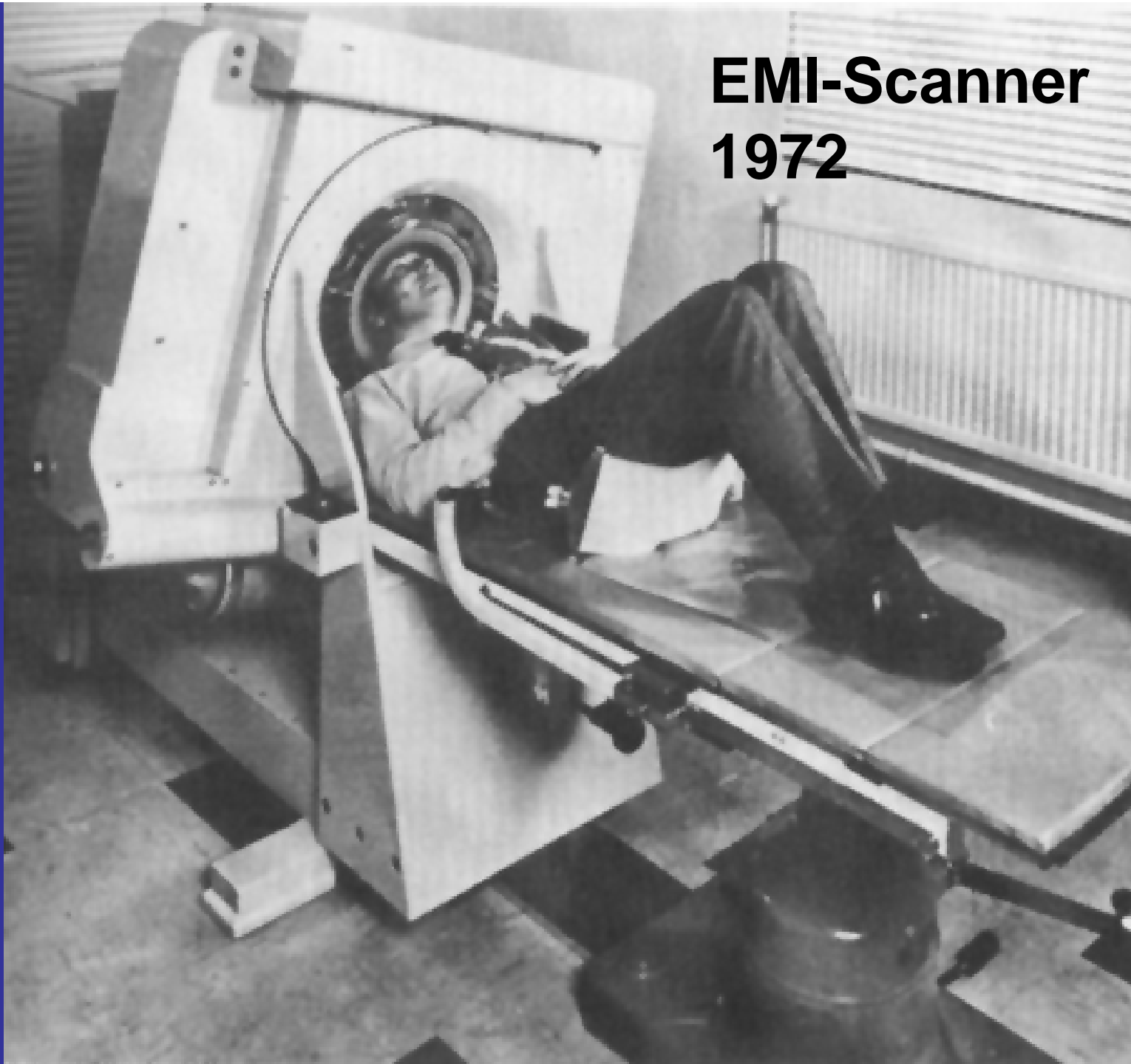
Computertomographie



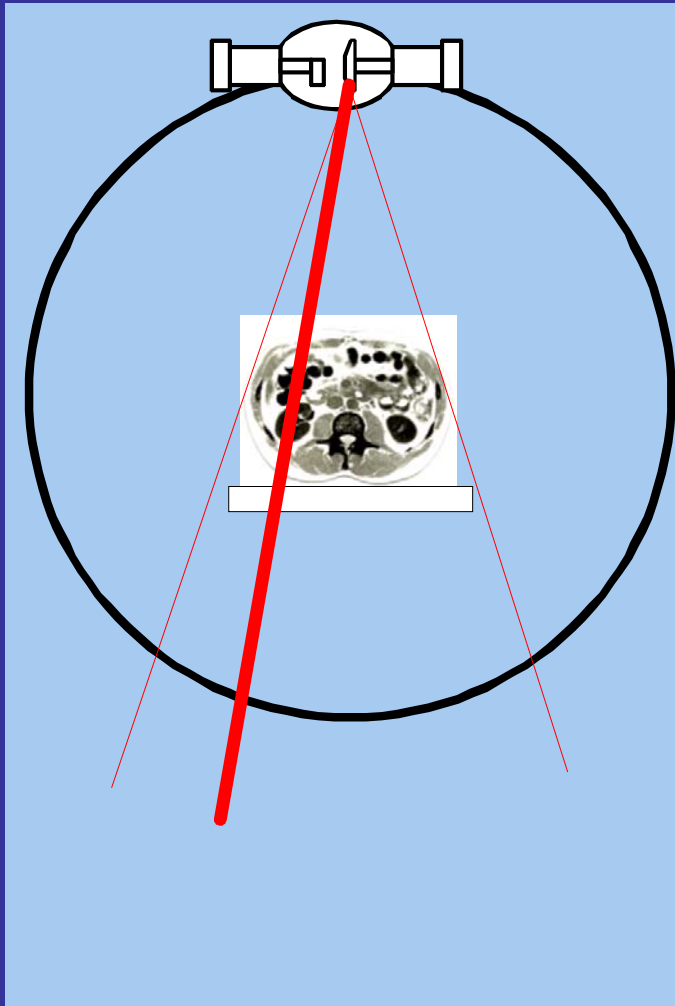
Scanning-Methoden

- Nadelstrahl
- Translation
- Rotation

EMI-Scanner 1972



Computertomographie

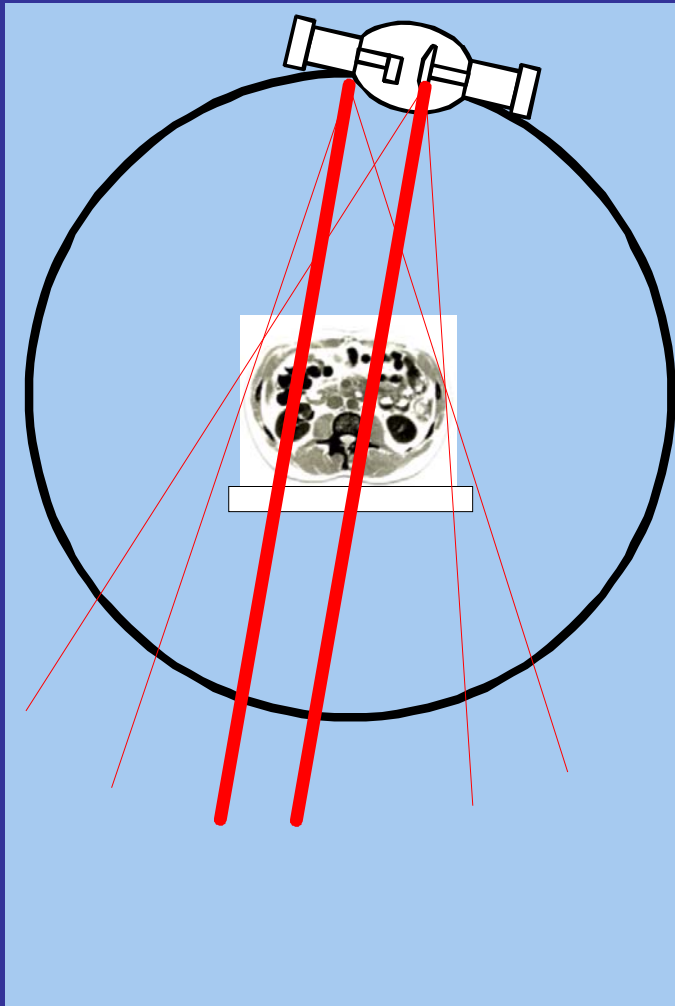


Scanning-Methoden

Fan-Beam-Geometrie

- Divergenz in Schnittebene
- Parallele Strahlen in verschiedenen Strahlenfächern

Computertomographie

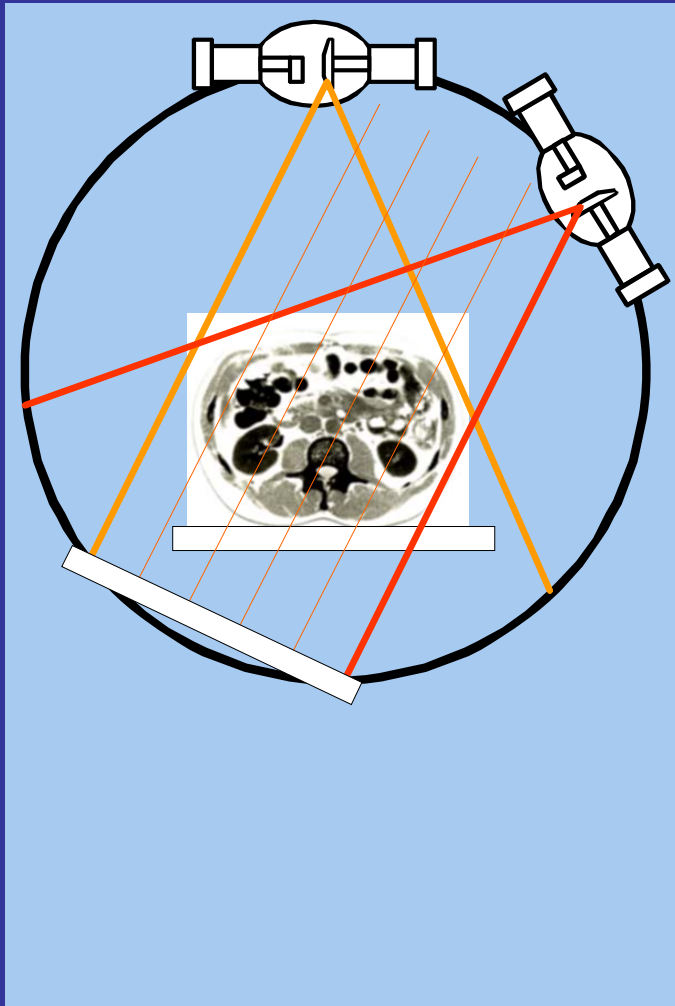


Scanning-Methoden

Fan-Beam-Geometrie

- Divergenz in Schnittebene
- Parallele Strahlen in verschiedenen Strahlenfächern

Computertomographie



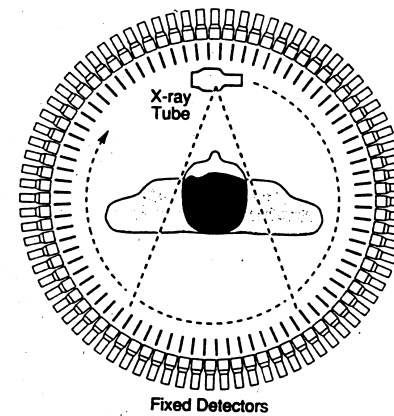
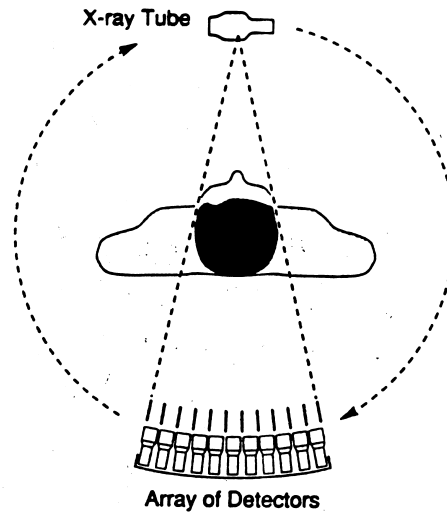
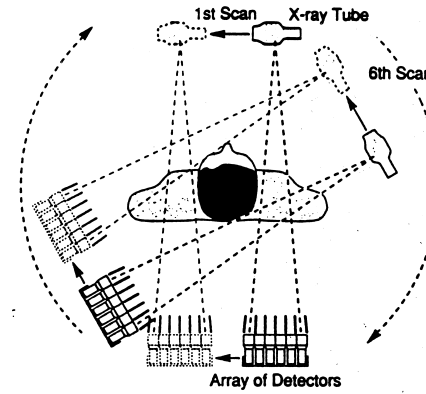
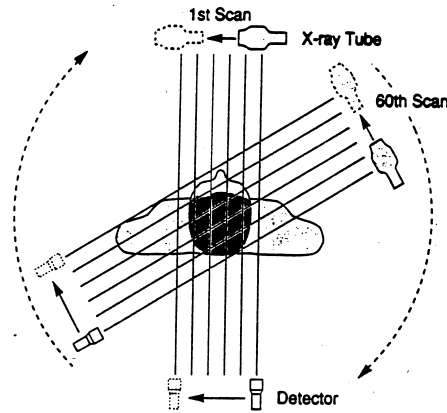
Scanning-Methoden

Fan-Beam-Geometrie

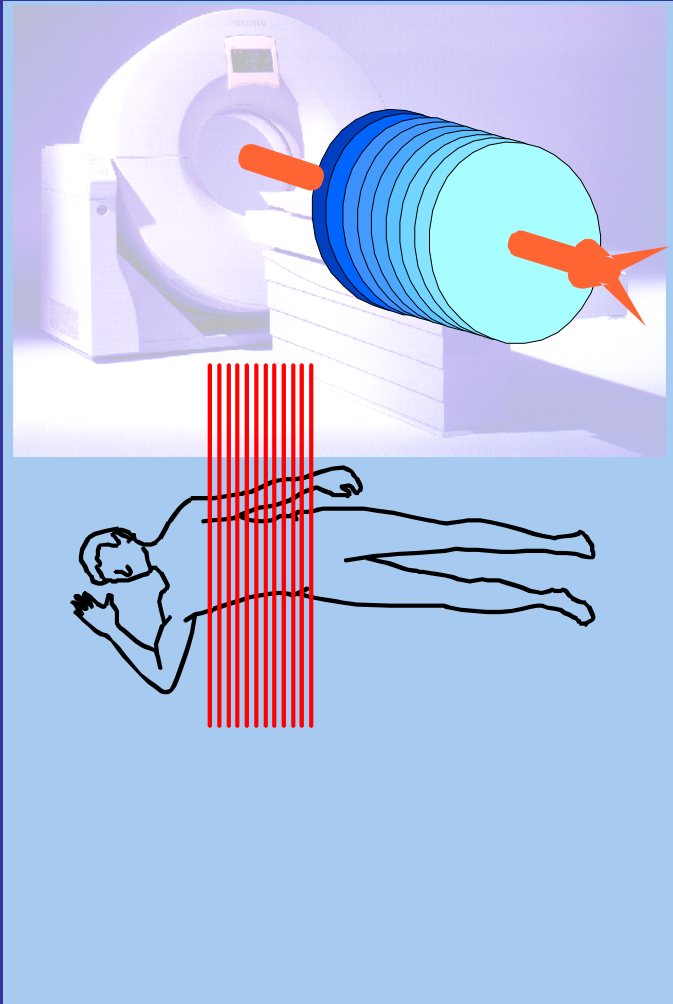
- Rotationsbereich enthält alle Strahlen zu einer Projektion
- Projektion durch Zusammenfügen der Parallelstrahlen berechnen

Computertomographie

Scanning-Methoden



Computertomographie

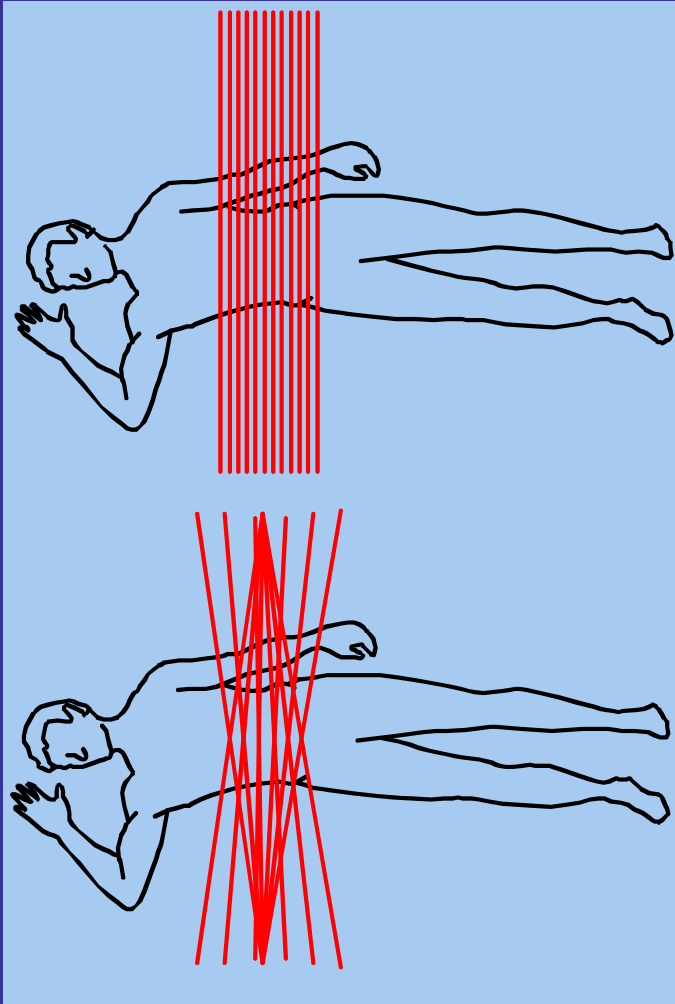


Scanning-Methoden

Schichtaufnahmen

- Bildstapel
- Bildebenen nicht zwingend parallel

Computertomographie



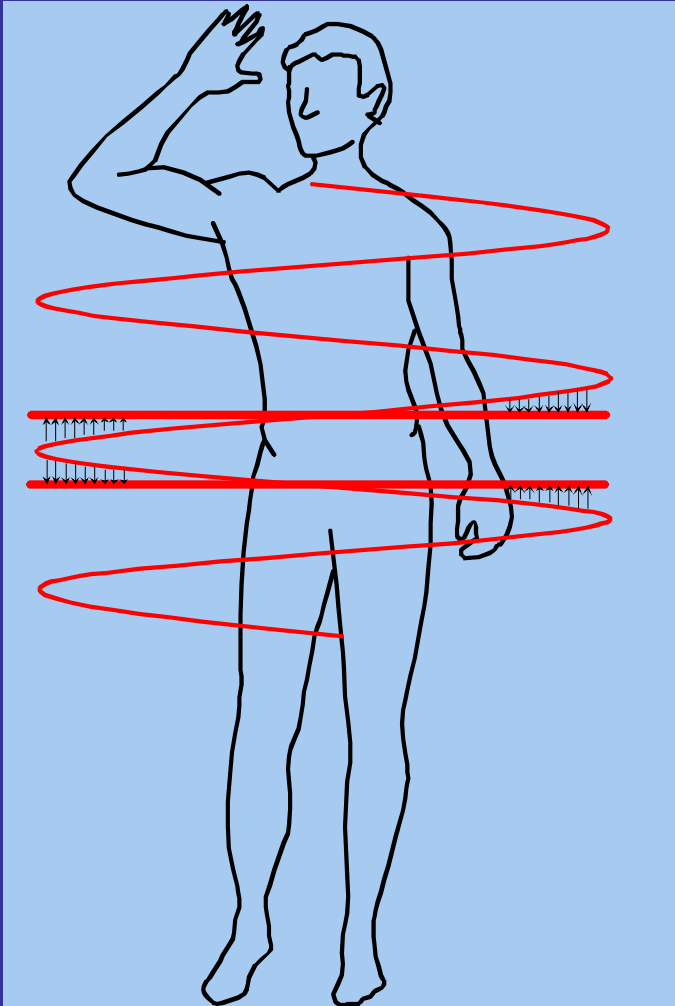
Scanning-Methoden

Cone-Beam-Technik

- Divergenz in Bildebene
- Divergenz in Längsrichtung

→ Strahlenkegel

Computertomographie

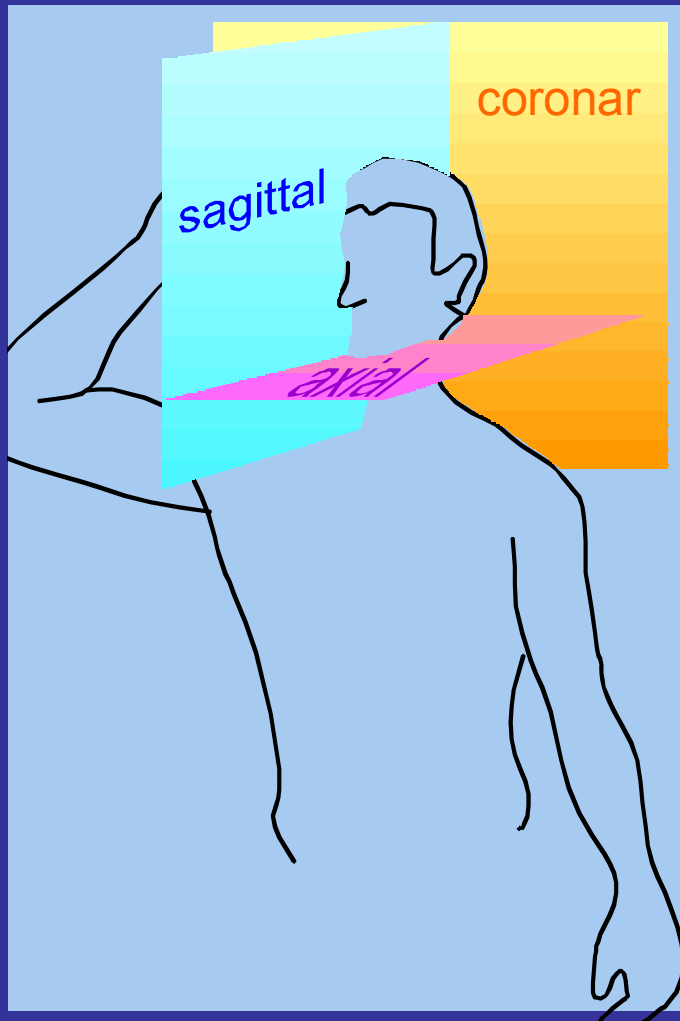


Scanning-Methoden

Spiral-CT

- Keine Parallelprojektion
- Divergenz zwingt zur Interpolation

Computertomographie

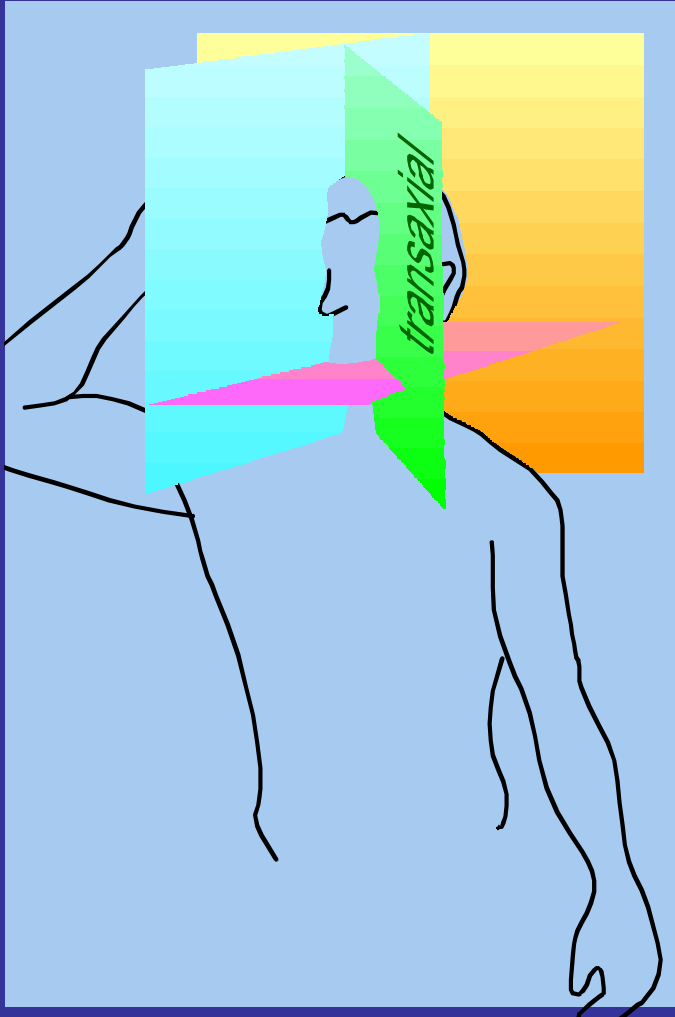


Scanning-Methoden

Rekonstruktion der Bildebenen

- Axial
- Sagittal
- Coronar

Computertomographie



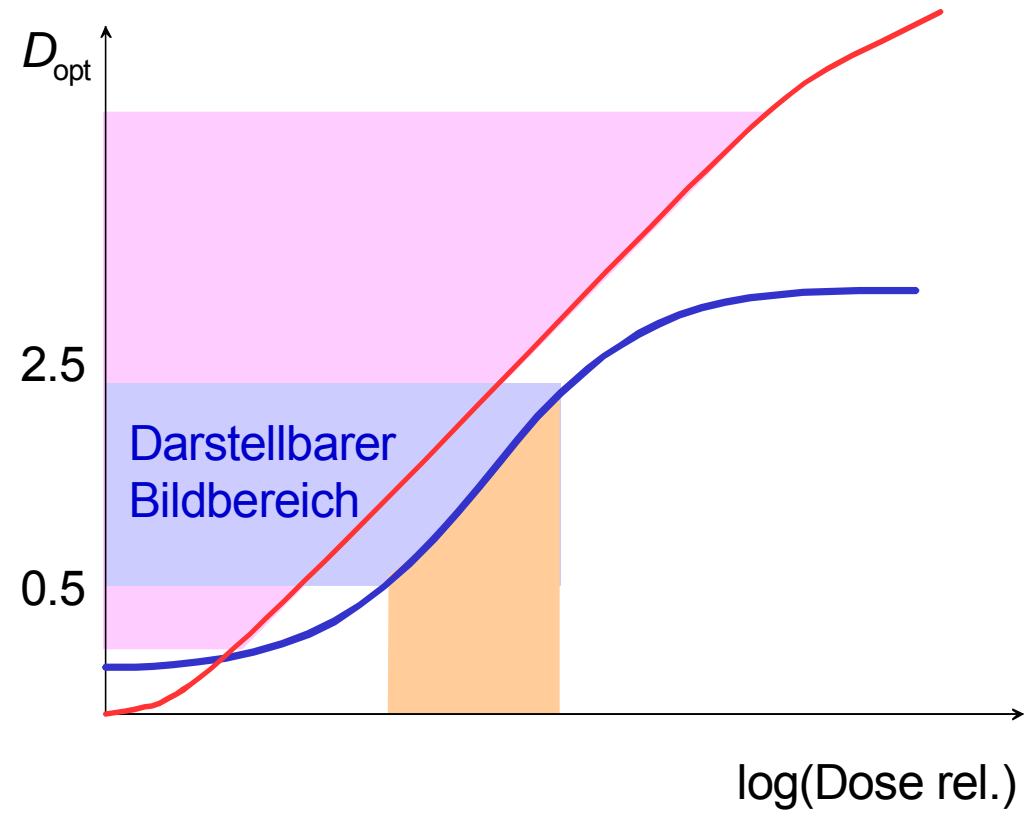
Scanning-Methoden

Rekonstruktion der Bildebenen

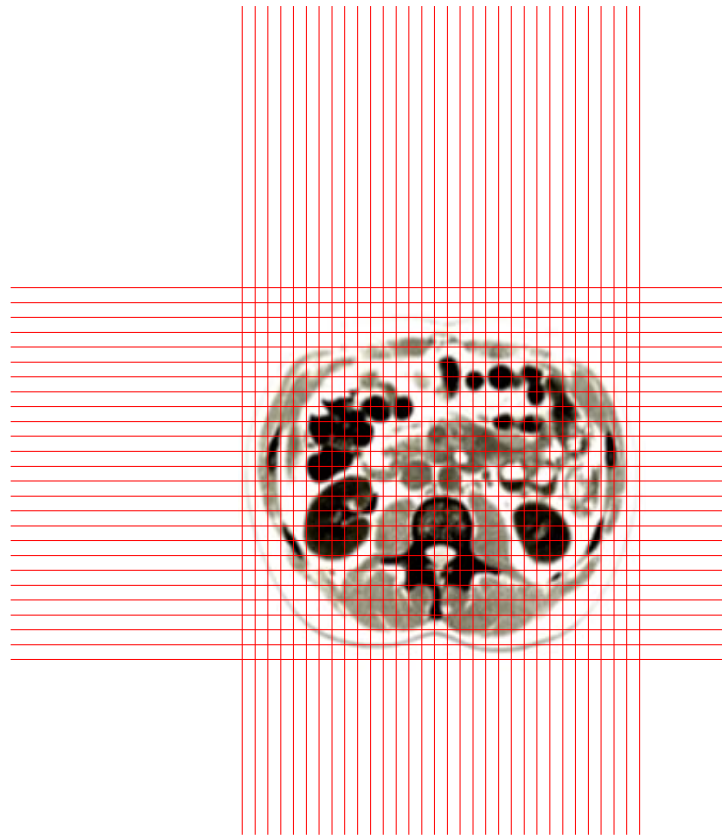
- Axial
- Sagittal
- Coronar
- Transaxial

Bildinhalt

``Fenster``

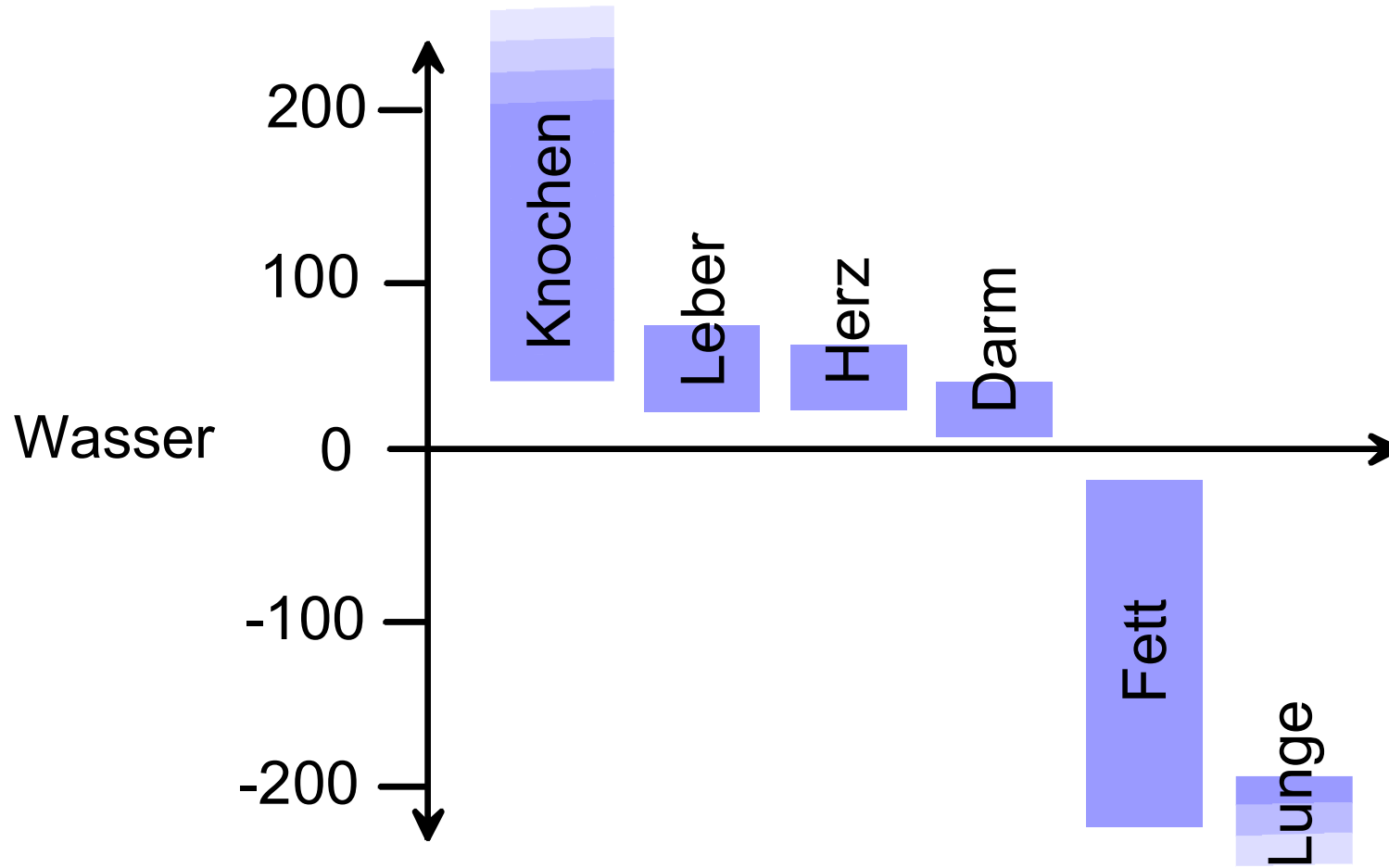


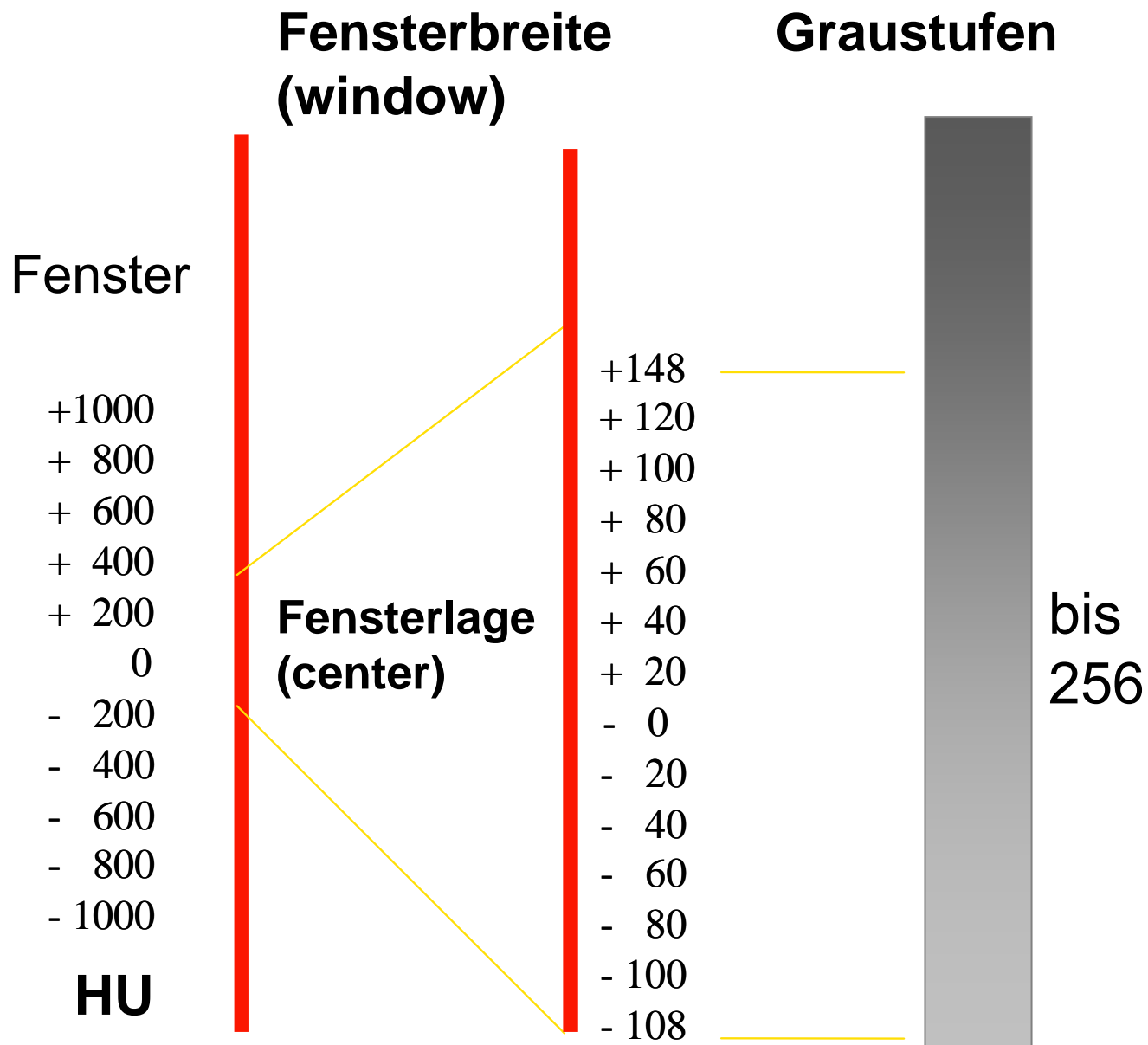
Hounsfield-Units



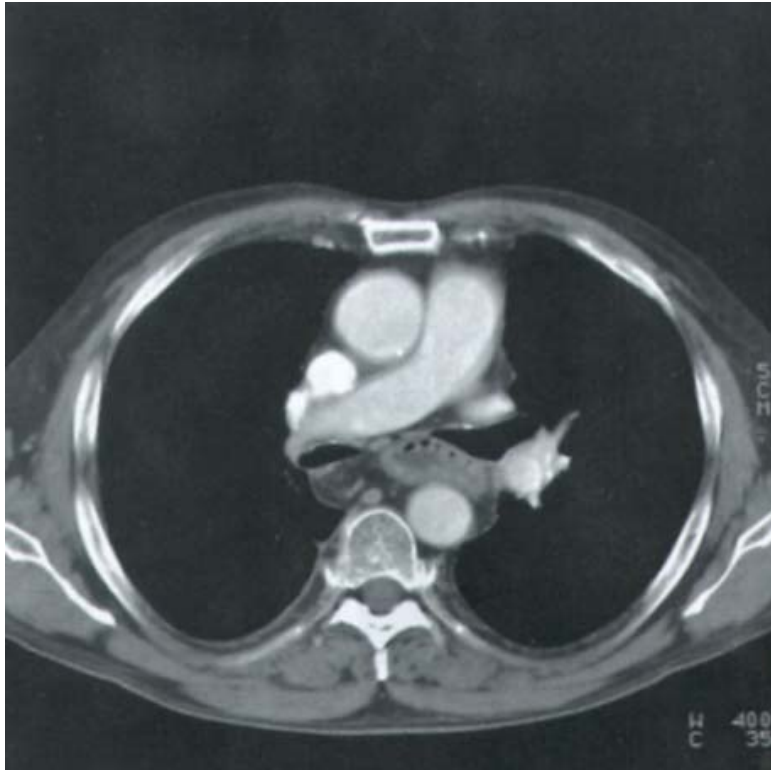
$$HU = \frac{\mu_x - \mu_{Wasser}}{\mu_{Wasser}} \cdot 1000$$

Hounsfield-Units

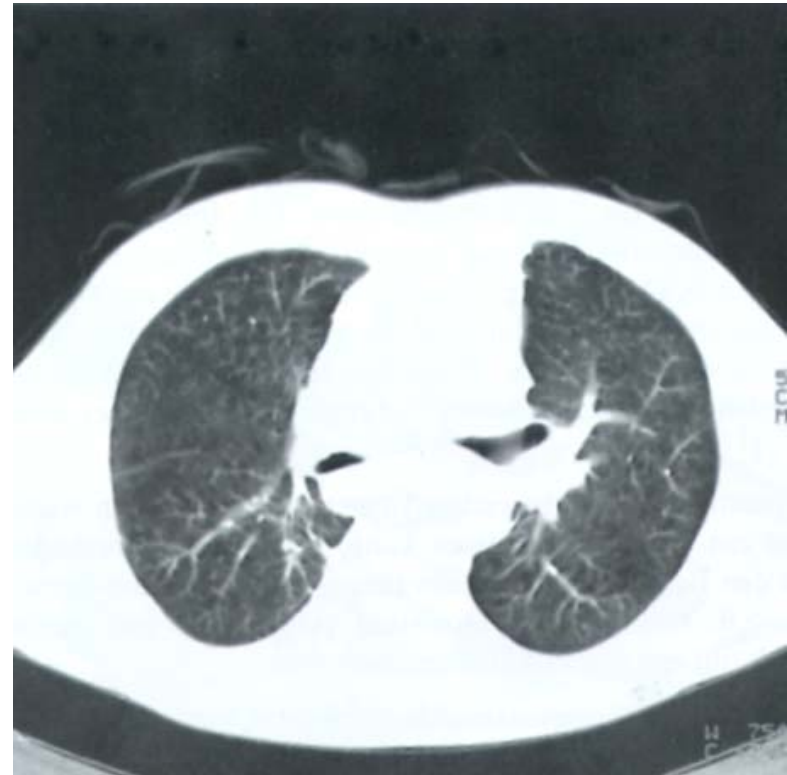




Fenster

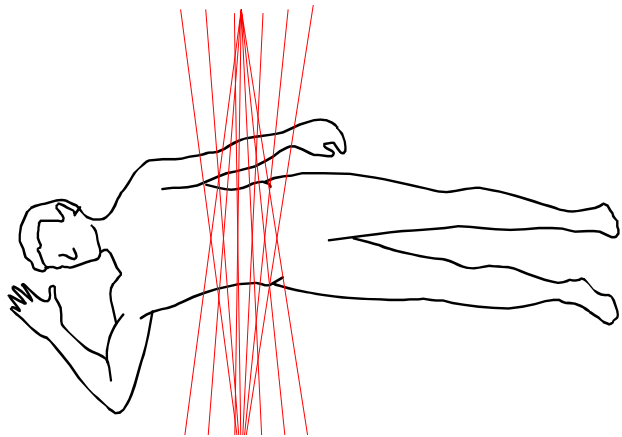
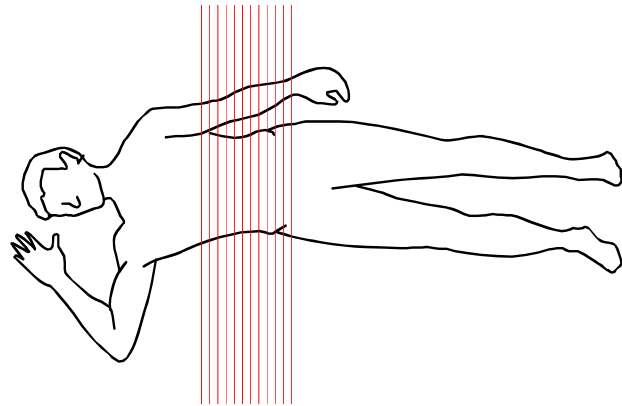


W 400 HU
C +45 HU



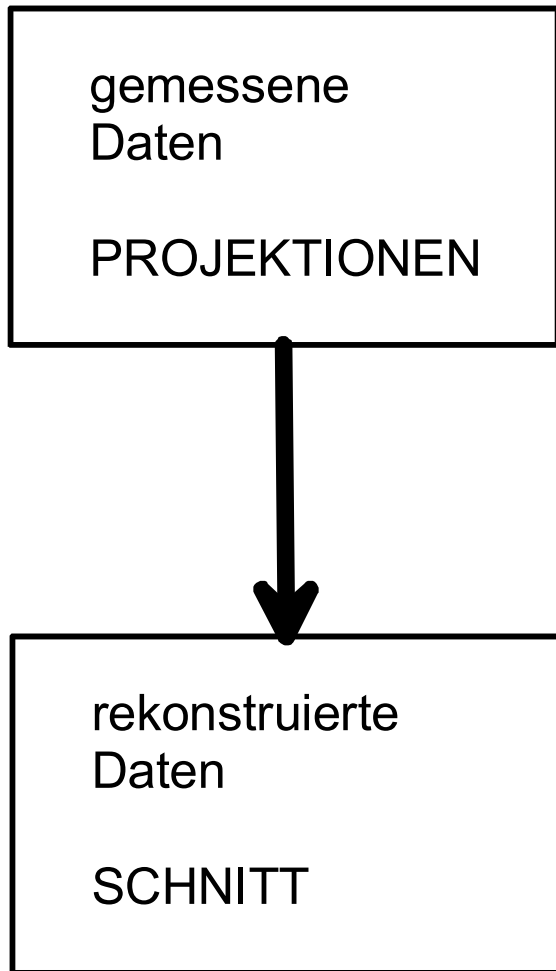
W 750 HU
C -720 HU

Auflösung bei CT

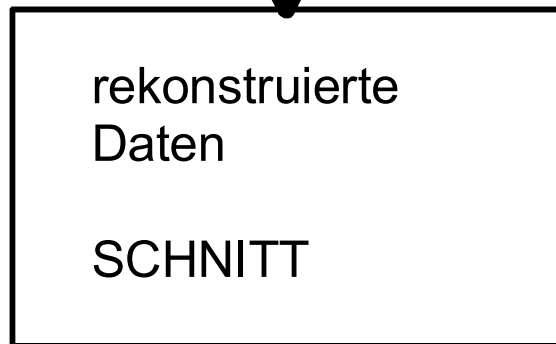
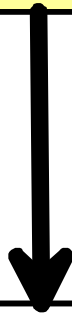
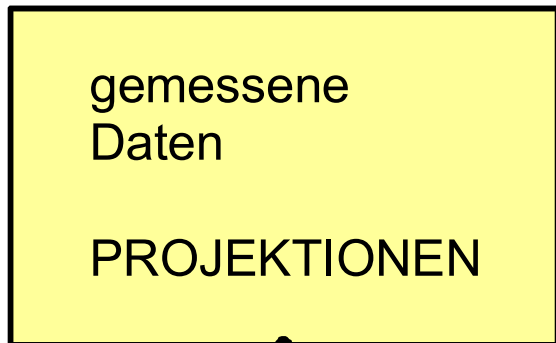


- ☀ Anzahl Projektionen
- ☀ Divergenz (Cone-Beam-Technik)
- ☀ Filter & Interpolationen
- ☀ Detektor

Artefakte bei CT



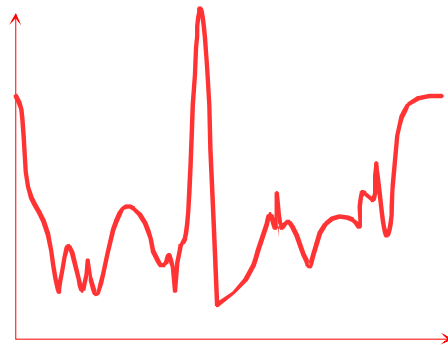
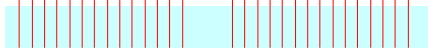
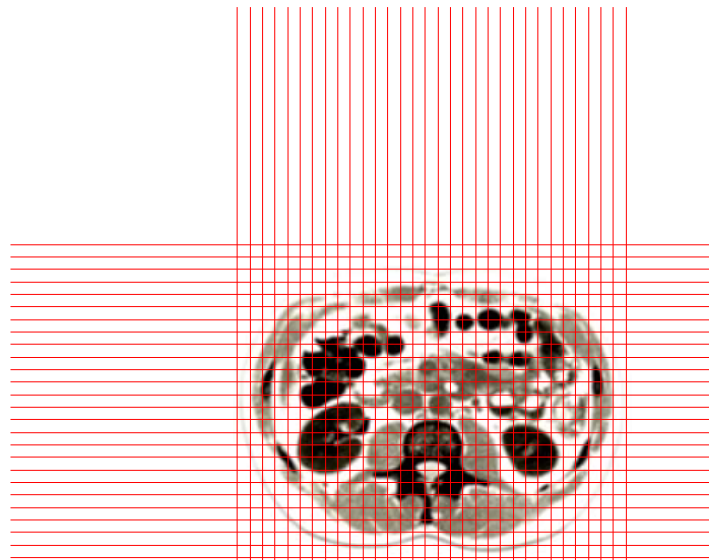
- ☀ Detektion
- ☀ Rekonstruktion
- ☀ Darstellung



Artefakte bei CT

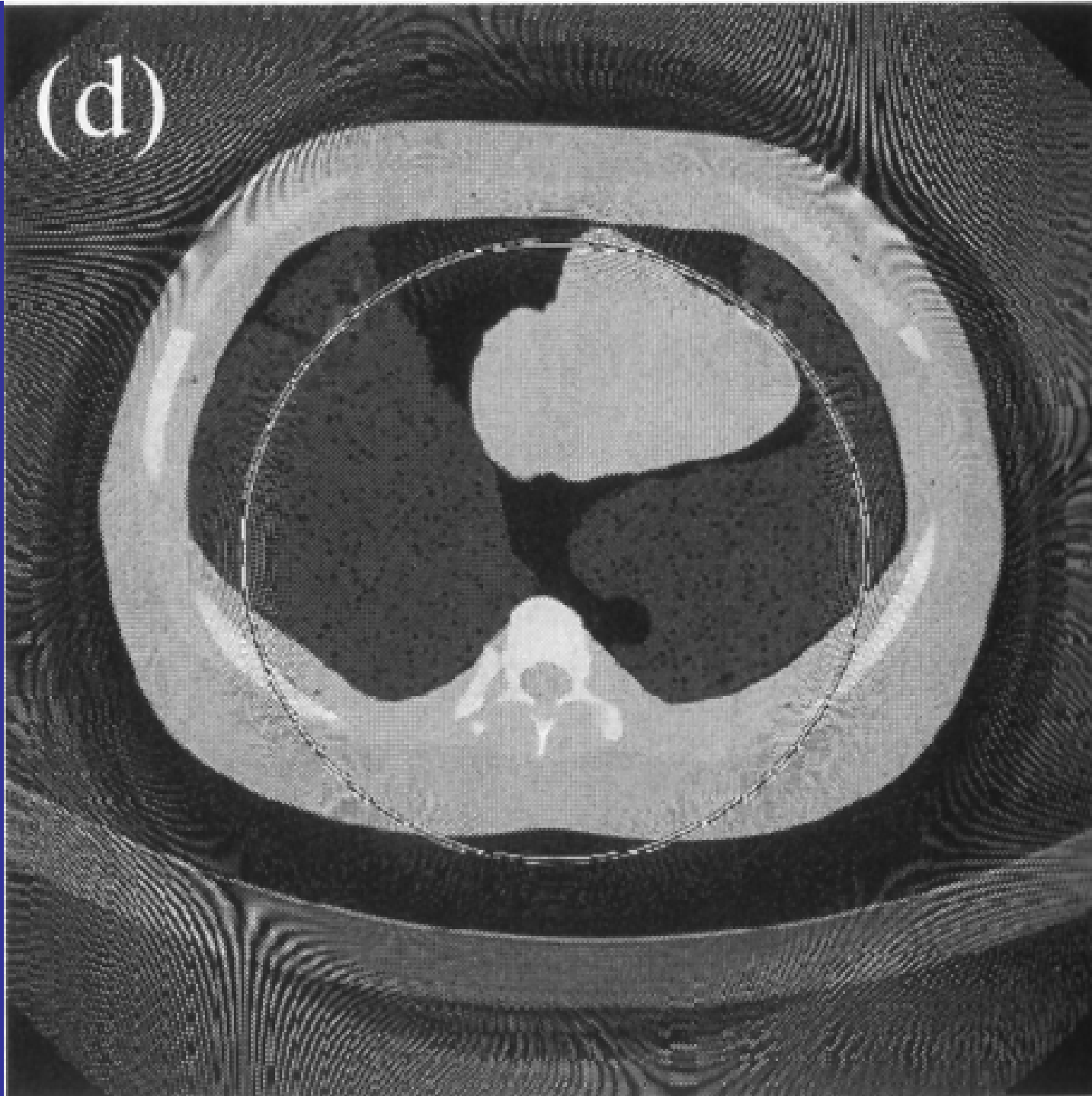
- ☀ partielle Detektion
- ☀ Partial Volume Artefakte
- ☀ Strahl-Aufhärtung
- ☀ Bewegungsartefakte

Partielle Detektion

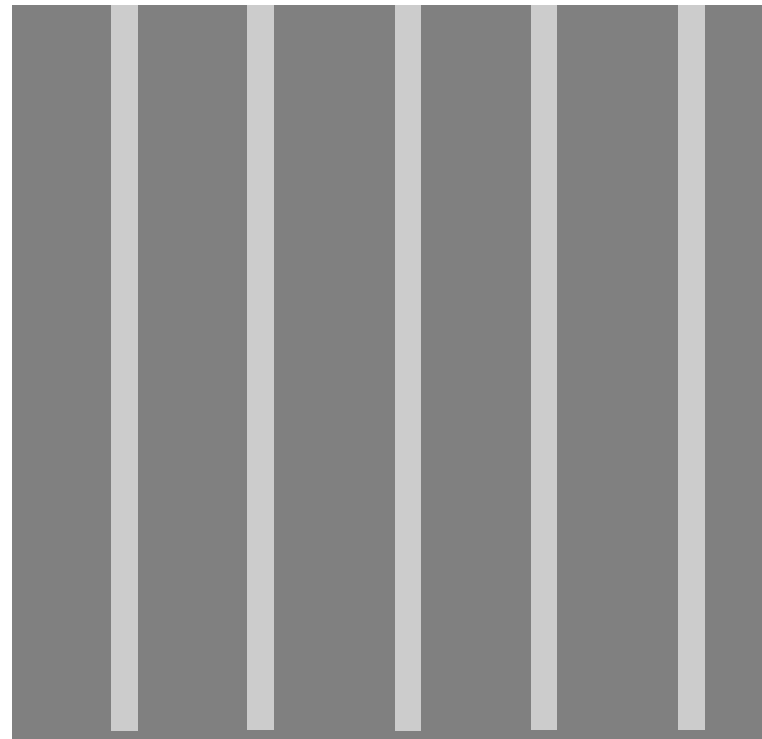
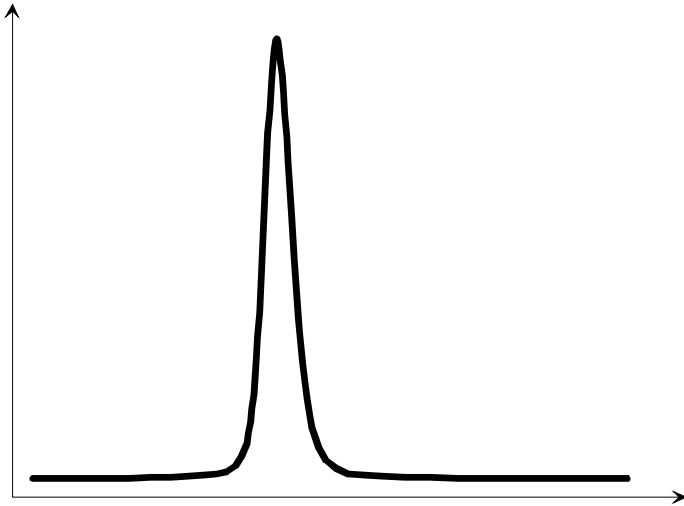


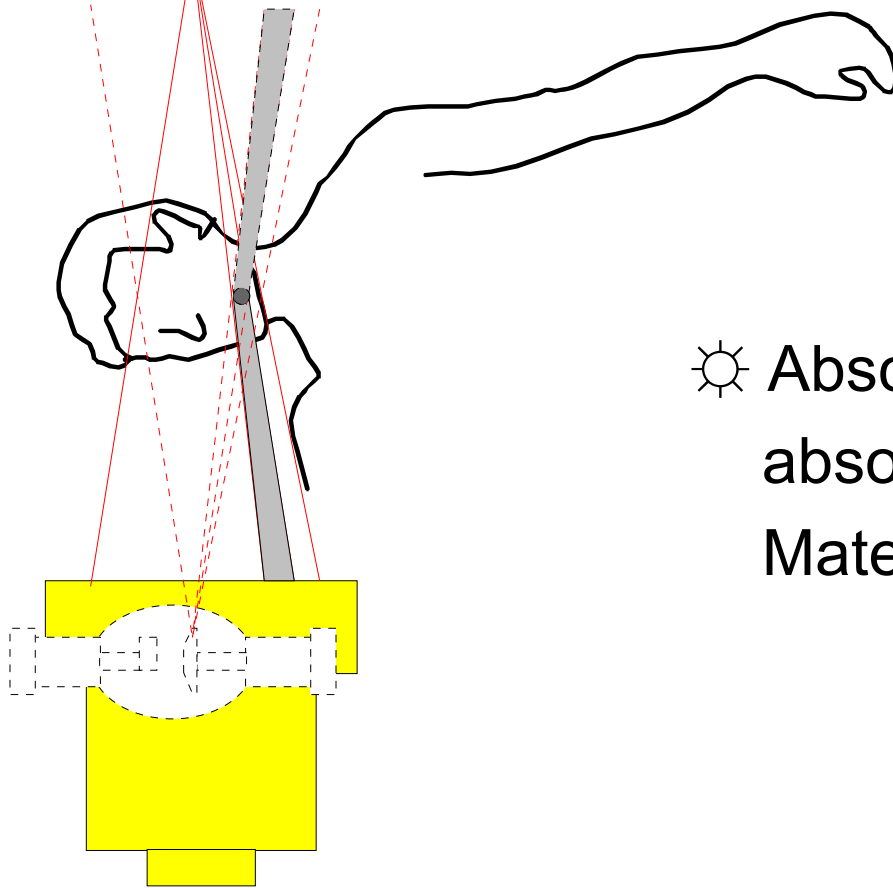
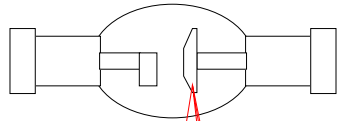
- ☼ defekter Detektor
- ☼ verschmutzter Detektor

(d)



Partielle Detektion

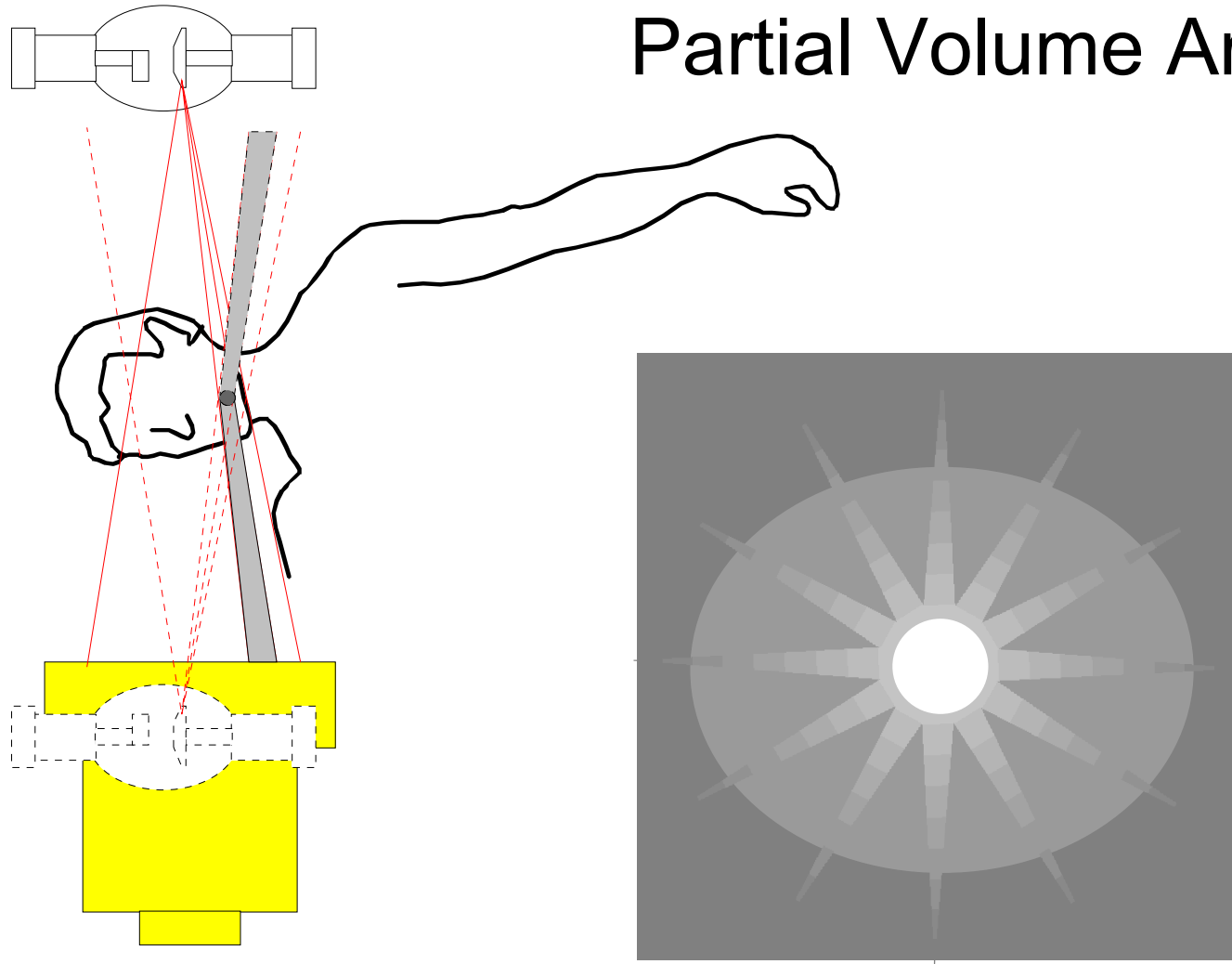




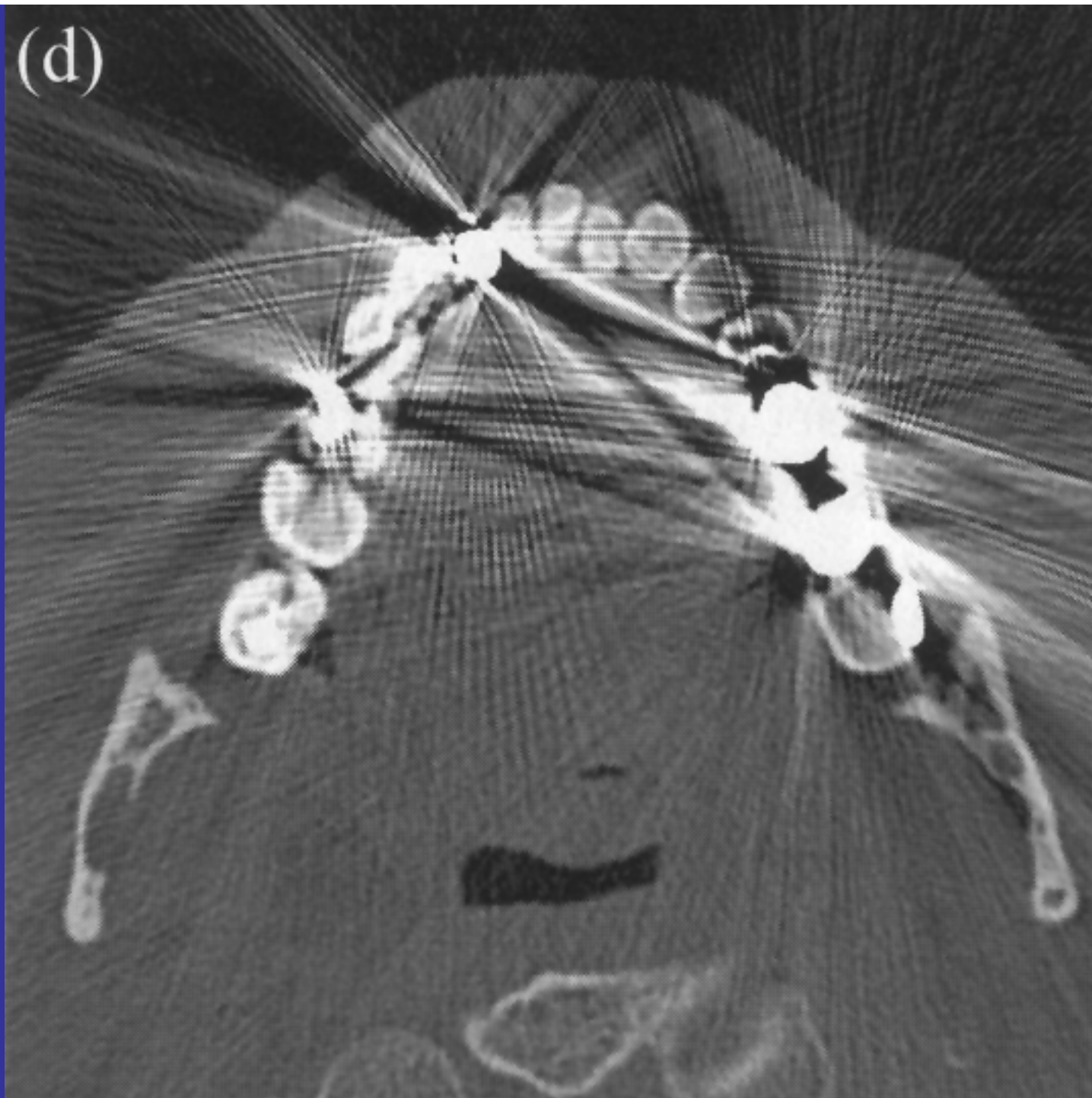
Partial Volume Artefakt

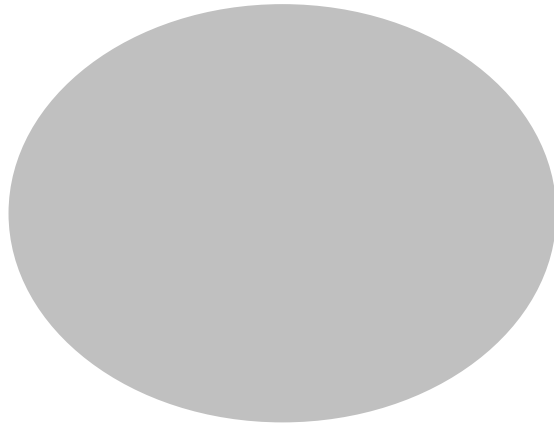
☀ Abschattung durch stark absorbierendes Material (Amalgam)

Partial Volume Artefakt

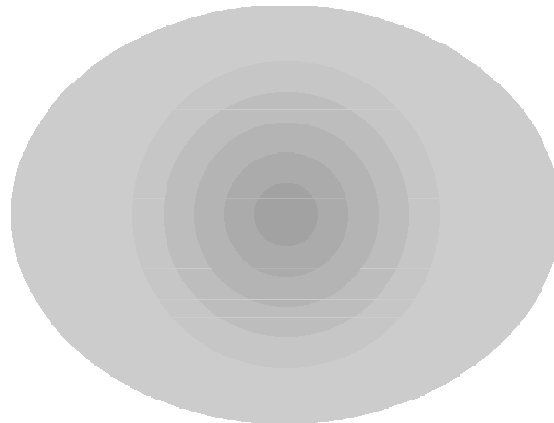


(d)

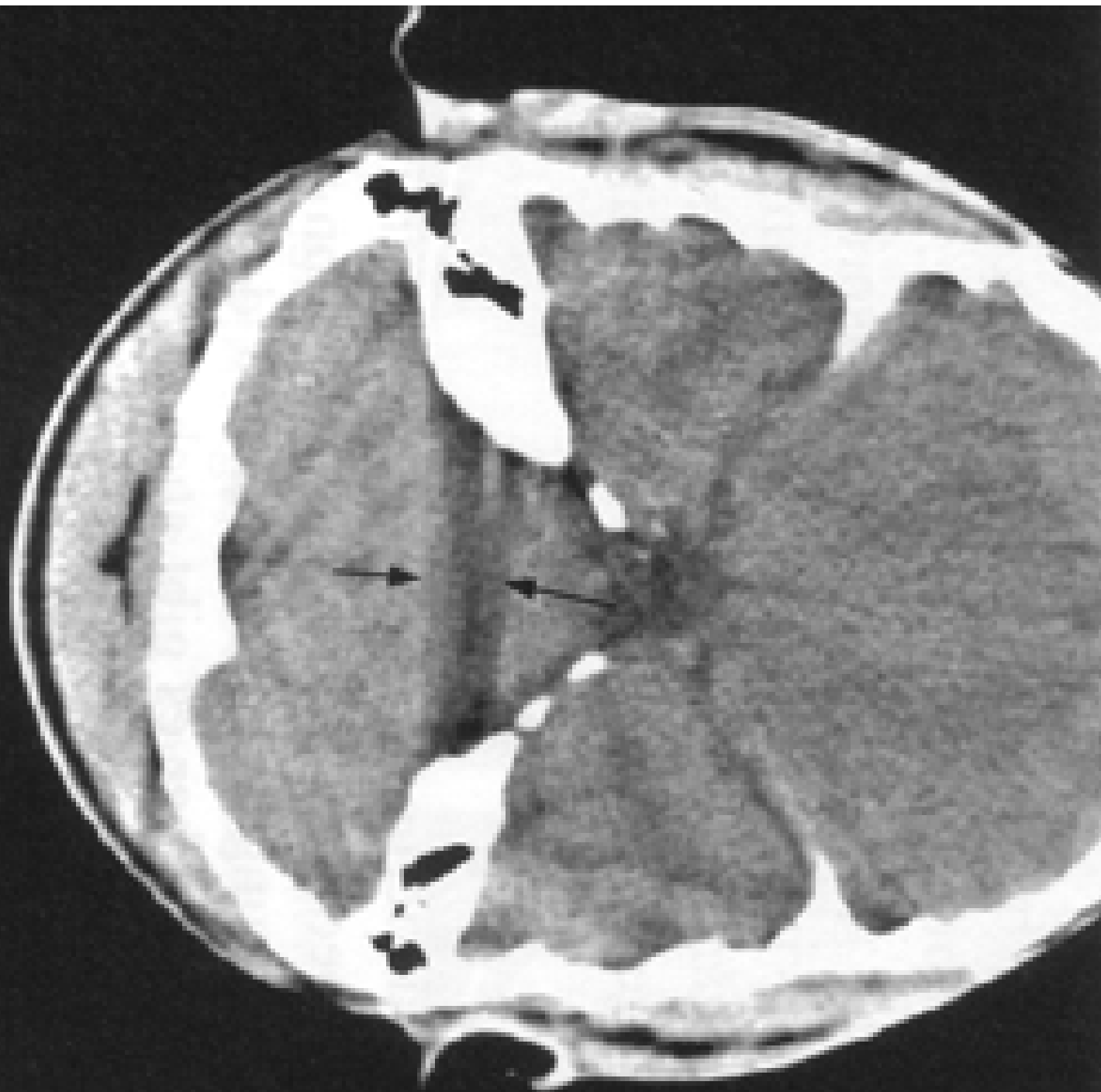




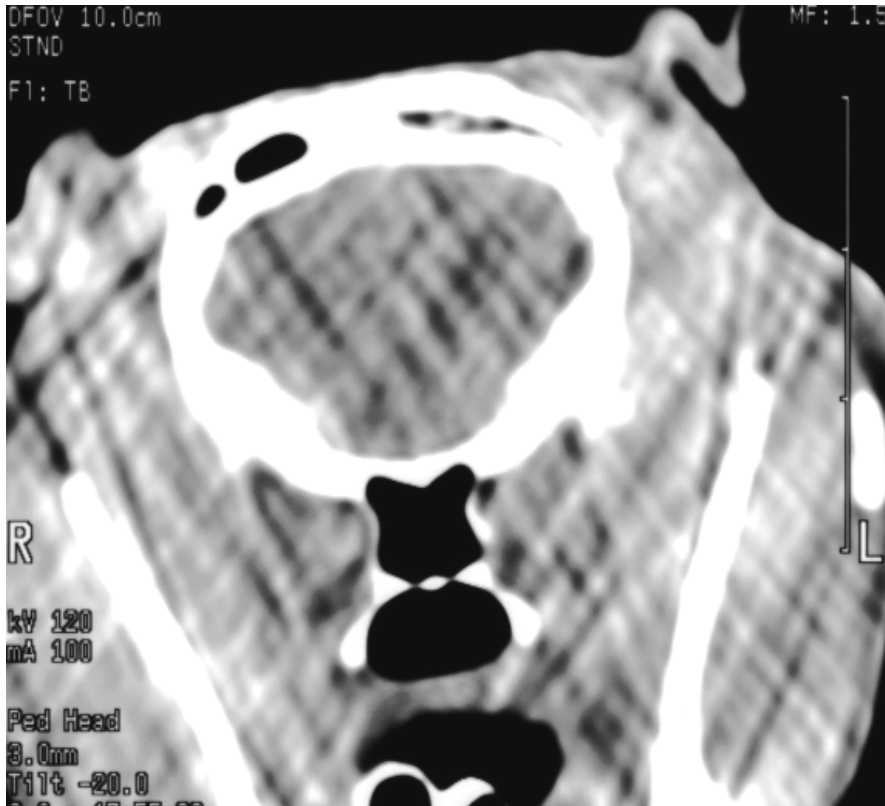
Strahlaufhärtung



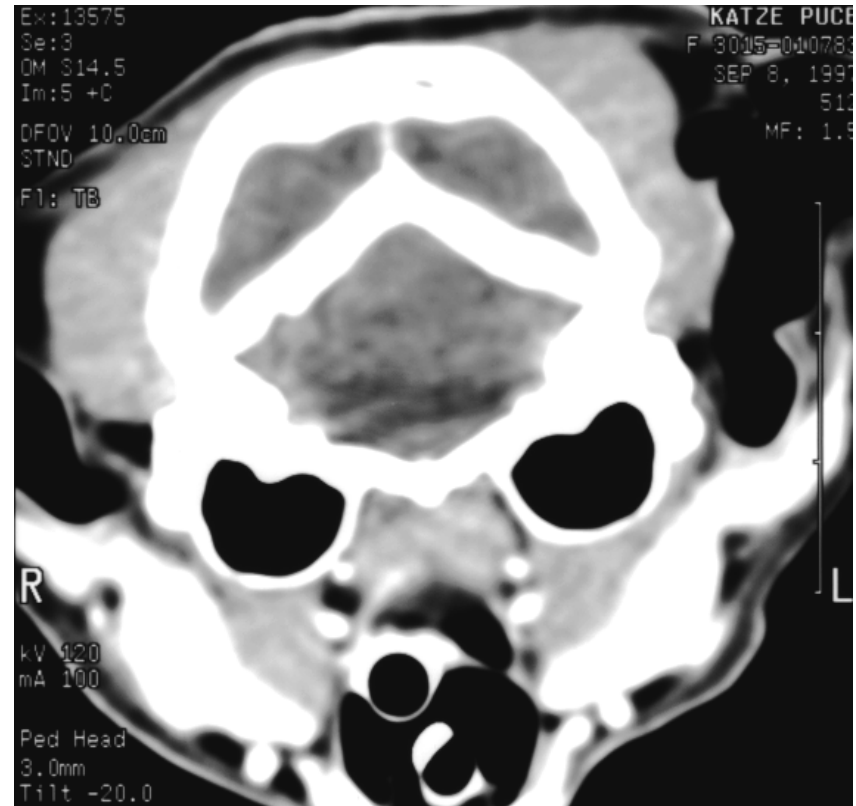
☀ Energie-Abhängigkeit
der Absorption



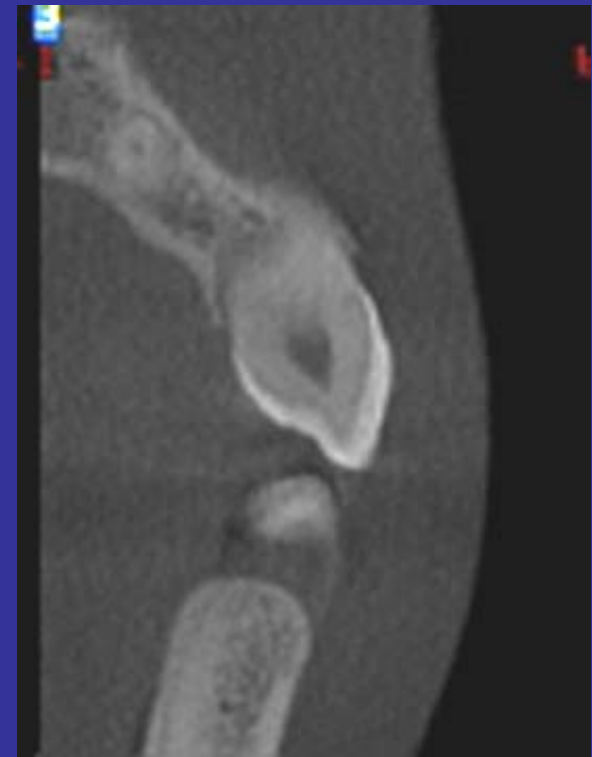
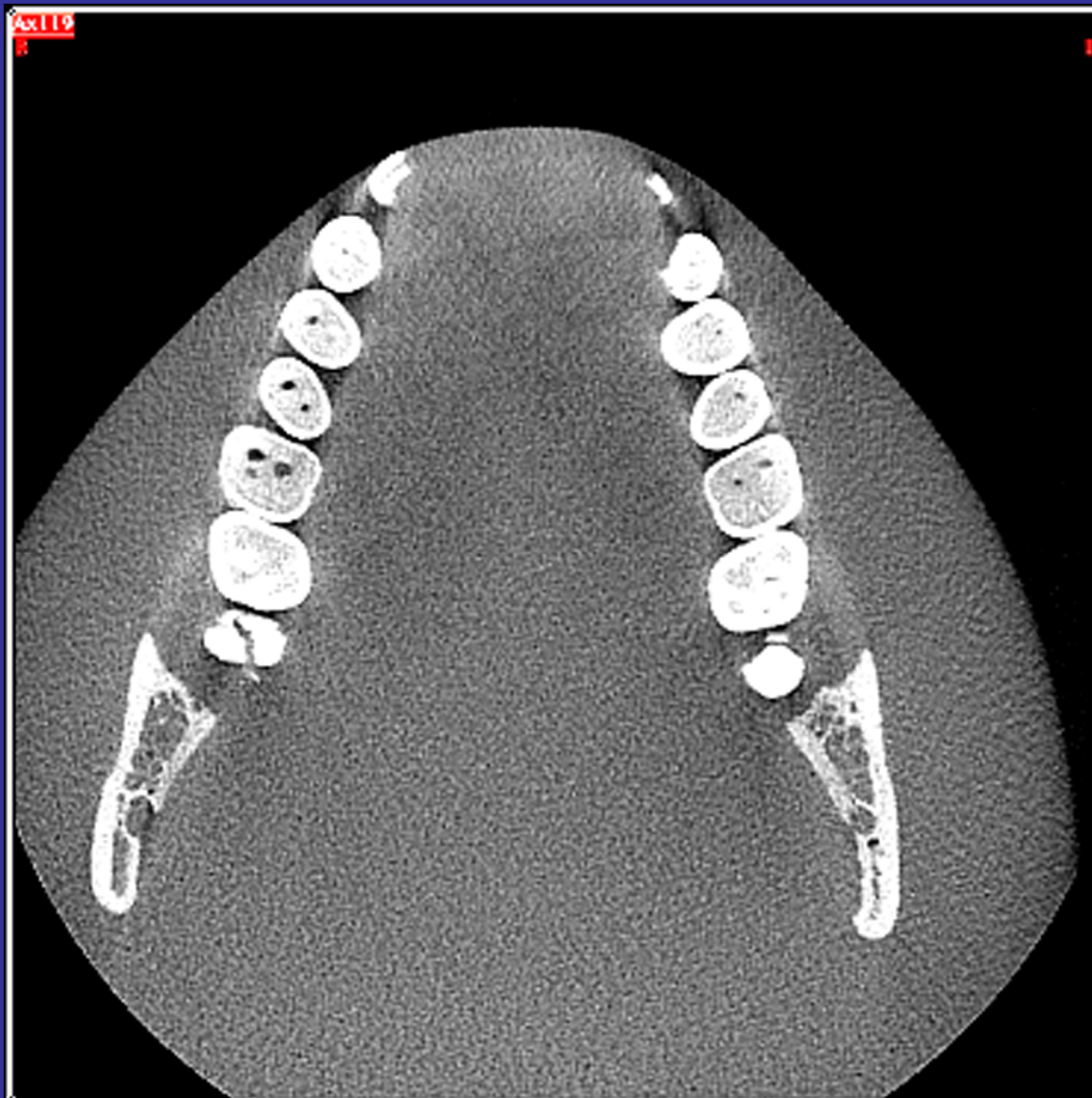
Artefakte bei CT

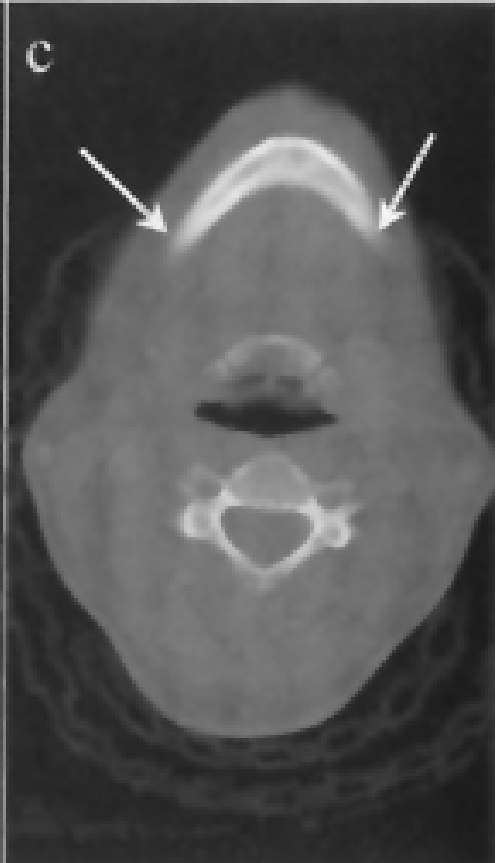
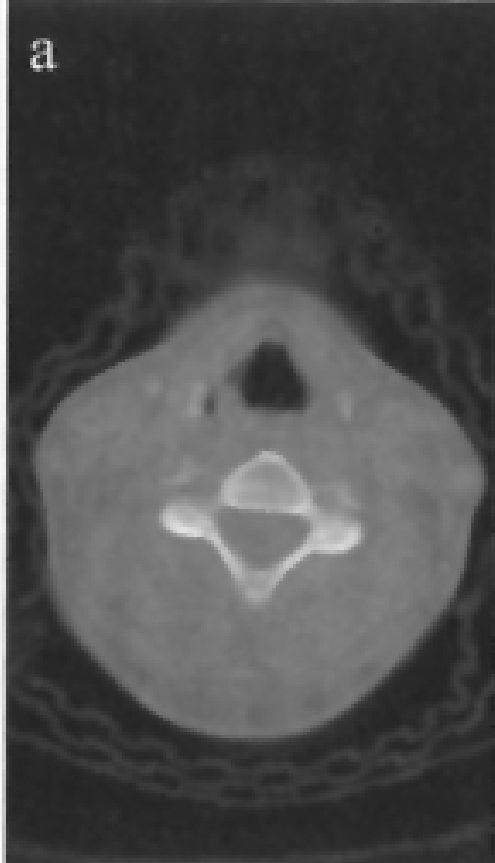
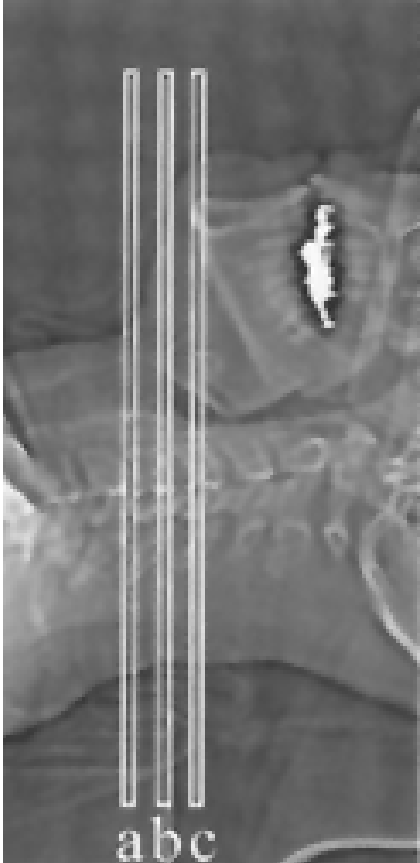


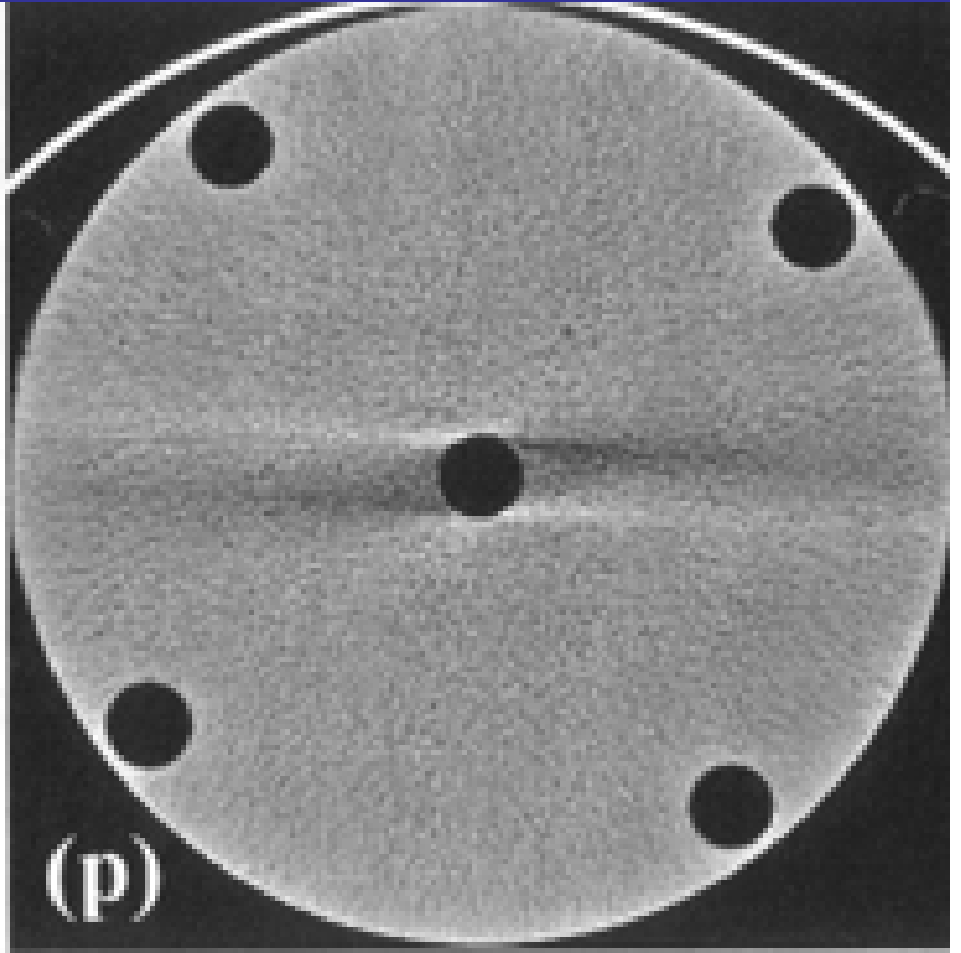
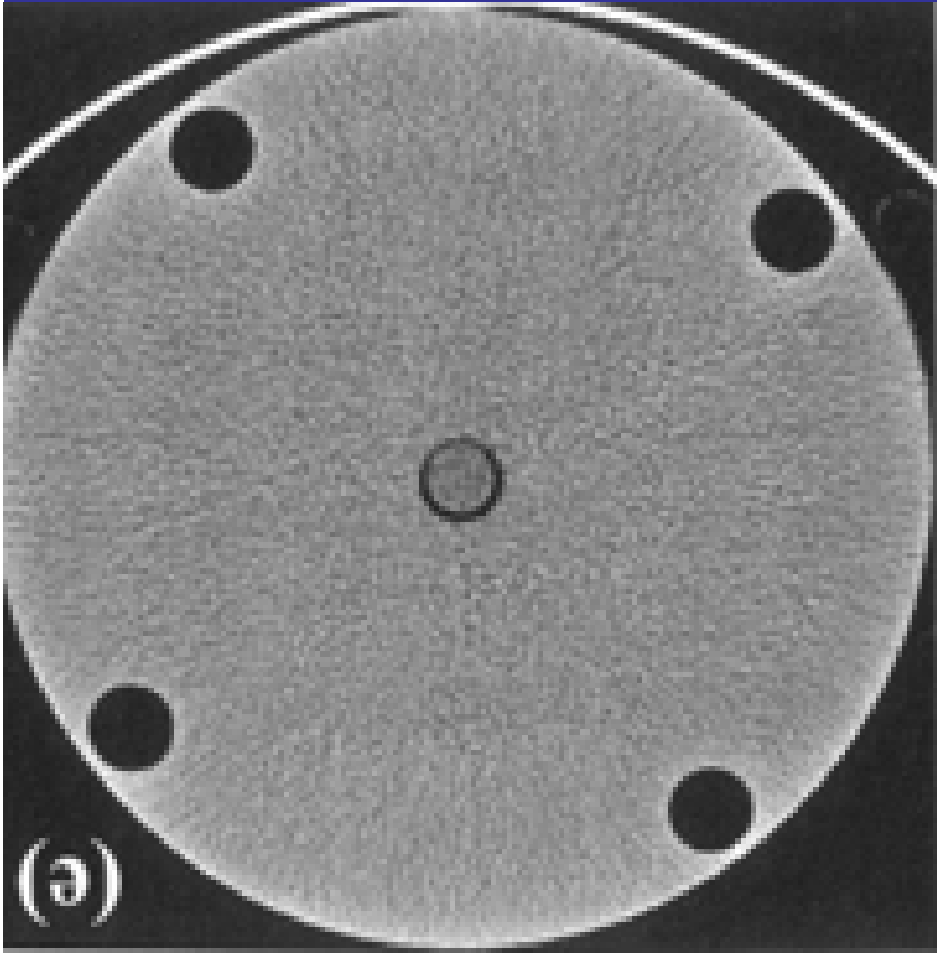
Streifenartefakte



Aufhartungsartefakt









The END