PAUL SCHERRER INSTITUT

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Introduction to Computed Tomography

Part IV: Geometry

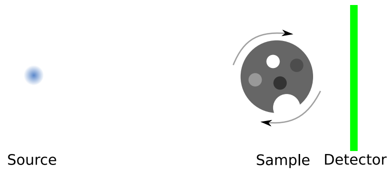
Outline

Lecture outline

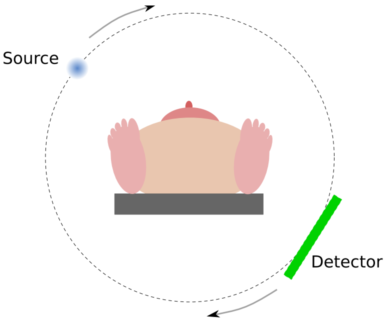
- Common beam geometry and their use
- Beam geometry for neutron imaging
- The importance of the acquisition axis

Different beamline configurations

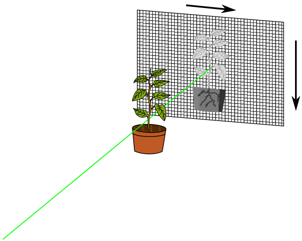
Static beamline



Rotating beamline

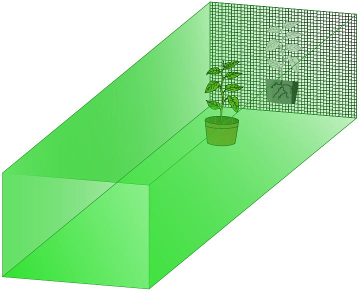


Pencil-beam



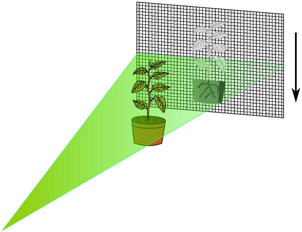
- Simples beam geometry
- Single pixels are scanned
- The 'Hounsfield-approach'

Parallel beam



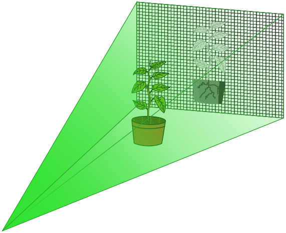
- Produces 2D projections
- No geometric unsharpness
- Simple reconstruction, filtered back projection [Buzug, 2008]

Fan beam



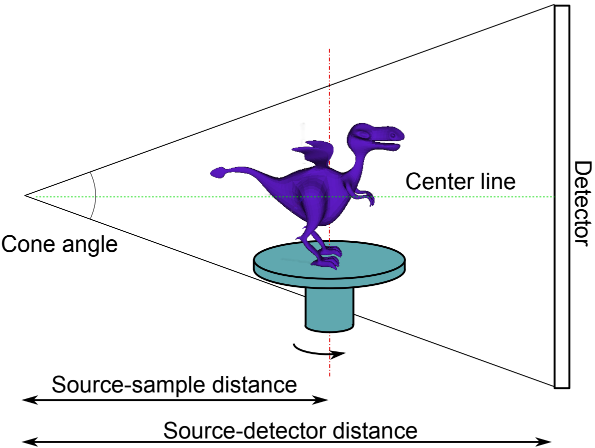
- Line-wise scan
- Beam incidence must be perpendicular to detector plane
- Magnifying in one direction

Cone beam

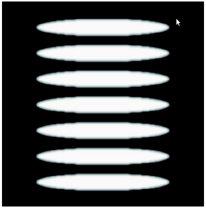


- + Uses 2D-projections.
- + Magnifying due to beam divergence.
- - Non-trivial reconstruction using [Feldkamp et al., 1984].
- - Only in the central slice is exact.

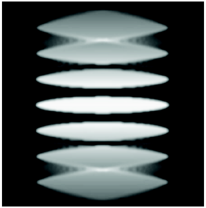
Problems with cone-beam



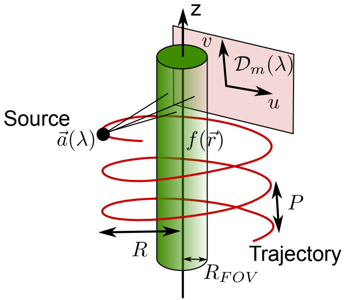
Parallel discs



FDK (cone angle 30°)



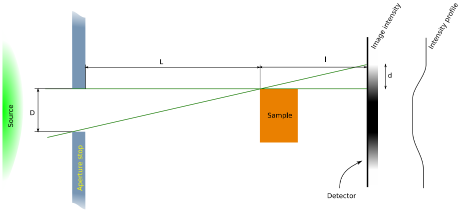
Helical scans



- Exact 3D solution
- Long objects
- Reconstruction using Katsevich[Katsevich, 2002]

Neutron imaging – Pin hole geometry

Penumbra blurring



Collimation ratio

The width of the penumbra blurring is described by the collimation ratio:

$$\frac{L}{D} = \frac{l}{d}$$

- L Distance from aperture to sample
- D Width of aperture diameter
- l Distance from sample to detector
- d Width of unsharpness

Beam divergence

Typical collimation ratio L/D = 100 – 2000 [mm/mm]

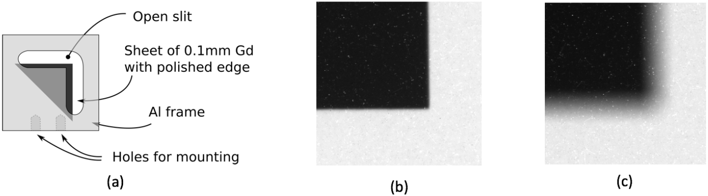


Fig 3. Schematic of the edge sample (a) and neutron radiographs obtained with the sample at 3mm (b) and 320mm (c) away from the detector. The edge unsharpness is mainly caused by penumbra blurring.

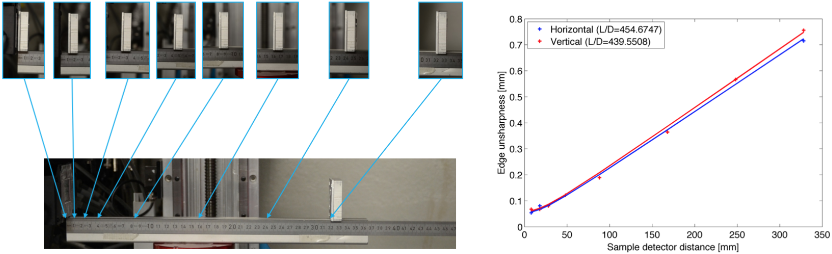
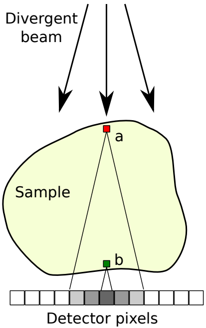
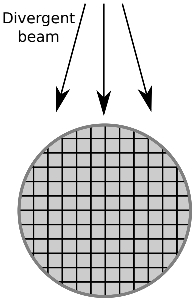


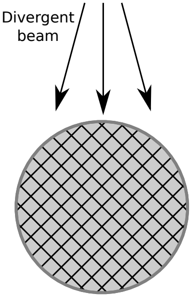
Fig 4. It is possible to estimate the collimation ratio by measuring the edge unsharpness at different distances from the detector.

[Kaestner et al., 2017]

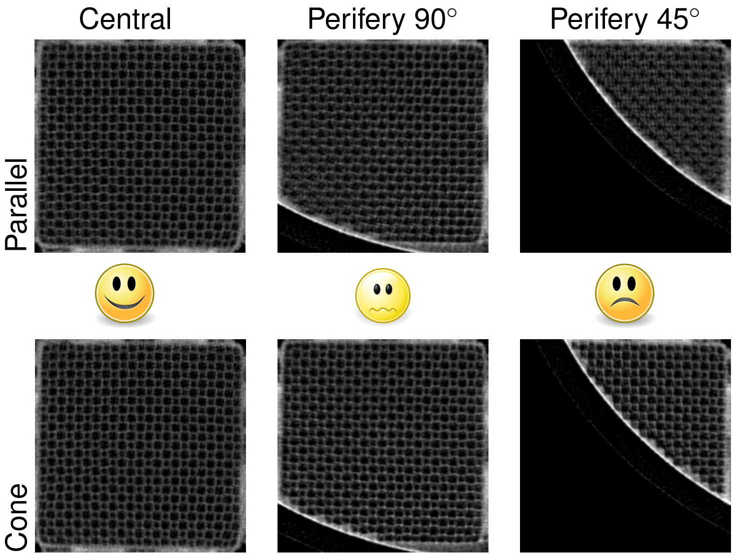
The impact of beam divergence







Improved results using CBCT reconstruction

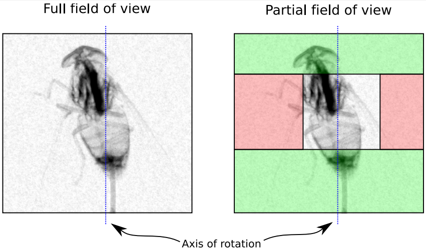


[Kaestner et al., 2012]

Large samples – The problem

Requirement

Projections from at least 180° + sample must always be visible.



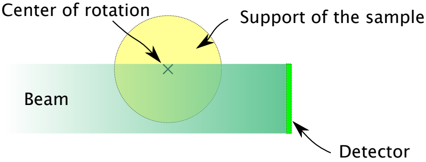
Two options to handle samples larger than the field of view

- Translate the COR and use a 360° orbit.
- Truncated reconstruction

Translated projections

Idea

- Translate the COR to the side of the projection
- Near doubled FOV



Requirements

- The projections must be stitched
- Projections must be acquired over 360°
- More voxels requires more projections

Truncated or Local tomography

A truncated tomography has incomplete data support.

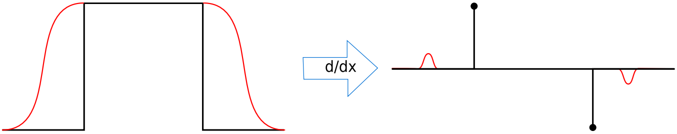
Effects of truncation

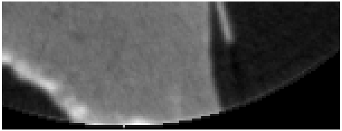
1. Some attenuation information is missing $\rightarrow$ bias
   The shadow contains more attenuation than the projection data shows.
2. Truncation gives spikes on the edges.
   The derivative in the reconstruction formula produce edge artifacts.

Removing truncation artifacts

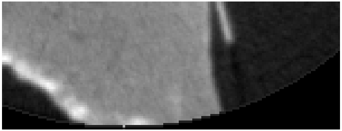
Origin The derivative of the truncated edge is steep

Solution Add a smooth transition from edge to zero



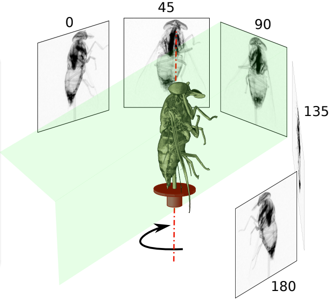


Original



Padded

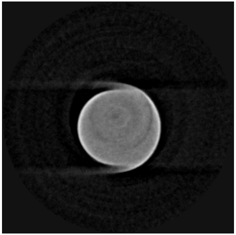
Position of the acquisition axis

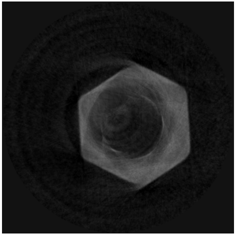


The axis

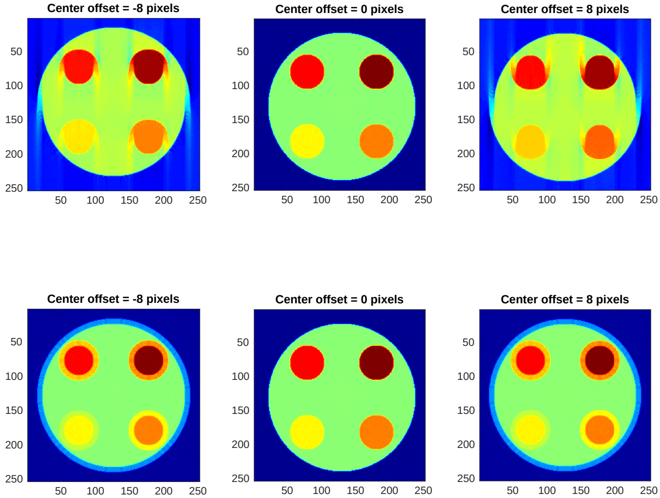
The point where all rays intersect is called the center of rotation for a single slice or the rotation axis for many slices. This point must be provided to the reconstructor.

Centering artifacts





The impact of center misalignment

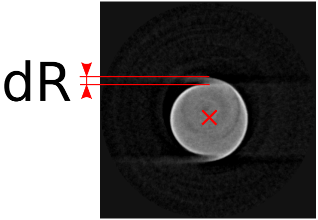


The finding center

Projection data

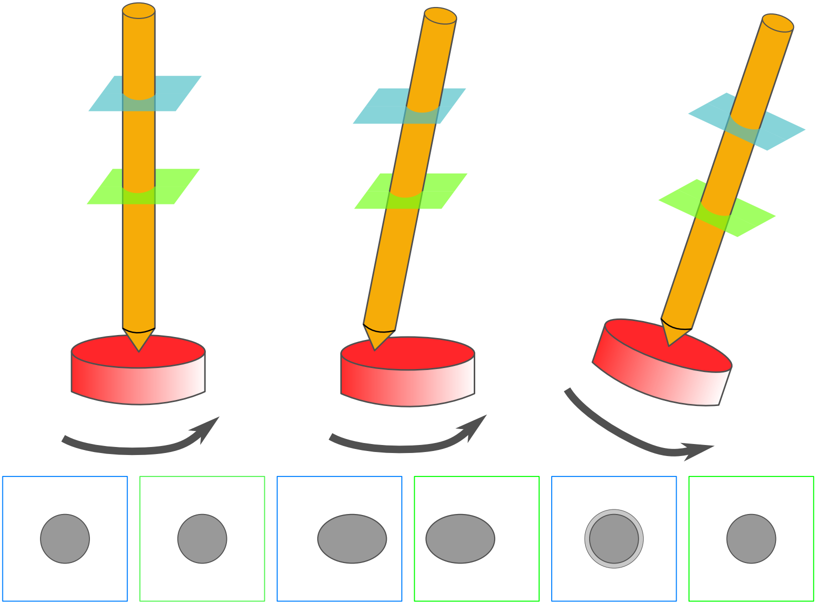
- Mirror one projection
- Translate until they overlap
- Center = midpoint + translation distance

Reconstructed data



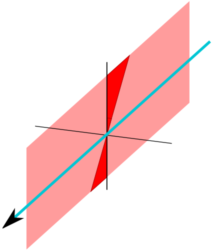
center = current $\pm$ dR/2

Tilted sample or table



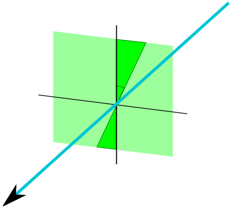
Tilted acquisition axis

Along the beam



- Hard to correct
- Requires vector based reconstructor and geometry

Across the beam



Small angles corrected with COR shifts

Large angles corrected with rotation

Summary

- In tomography, different beam geometries are used.
- Neutron imaging is approximately parallel.
- The acquisition axis is very important.
- The sample should be in the field of view.

References I

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