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ICTP 40th Anniversary

SCHOOL ON SYNCHROTRON RADIATION AND APPLICATIONS
In memory of J.C. Fuggle & L. Fonda

19 April - 21 May 2004

Miramare - Trieste, Italy

1561/34

Computed Tomography

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Computed Tomography

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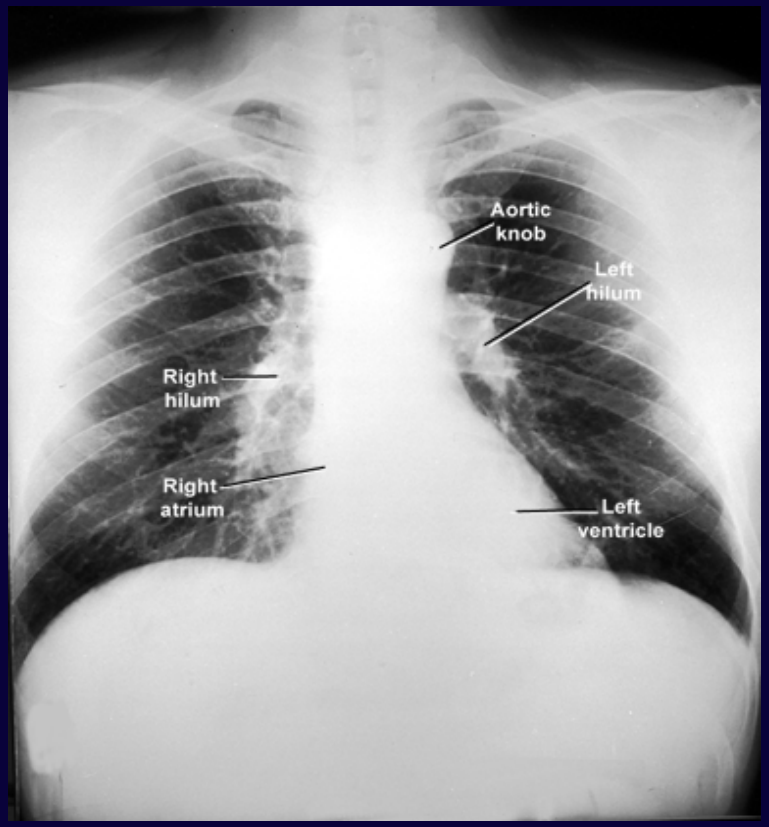
Summary

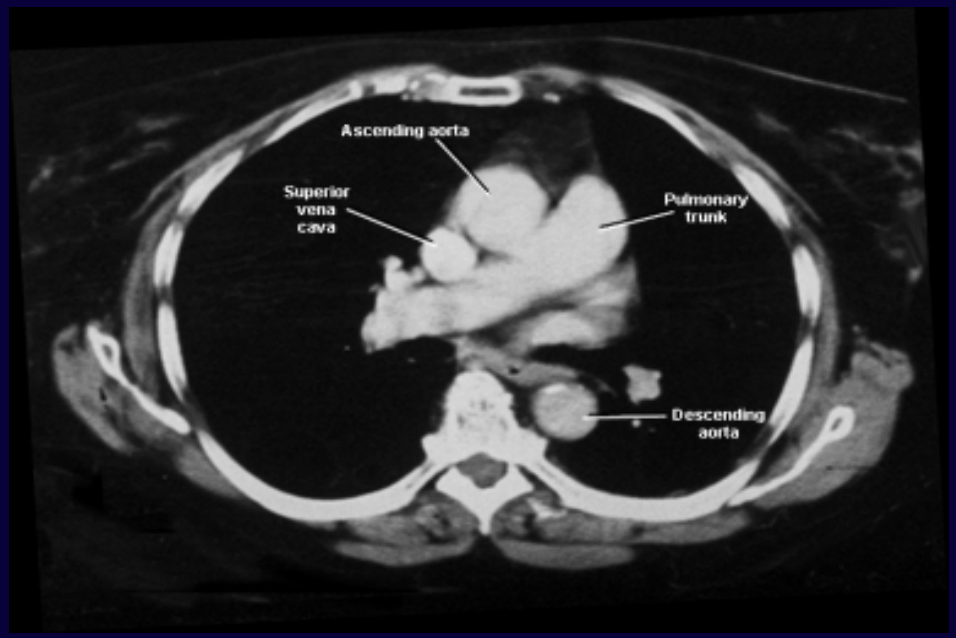
- Computed Tomography
  - Purpose
  - How does it work?
- CT reconstruction
  - Filtered backprojection
- Synchrotron radiation CT
- MicroCT at the SYRMEP beamline
- Further applications

The goal

- To provide a three-dimensional information (depth of the structures/organs)
- To provide information about the attenuation coefficient (tissue characterization)

From planar imaging... to CT



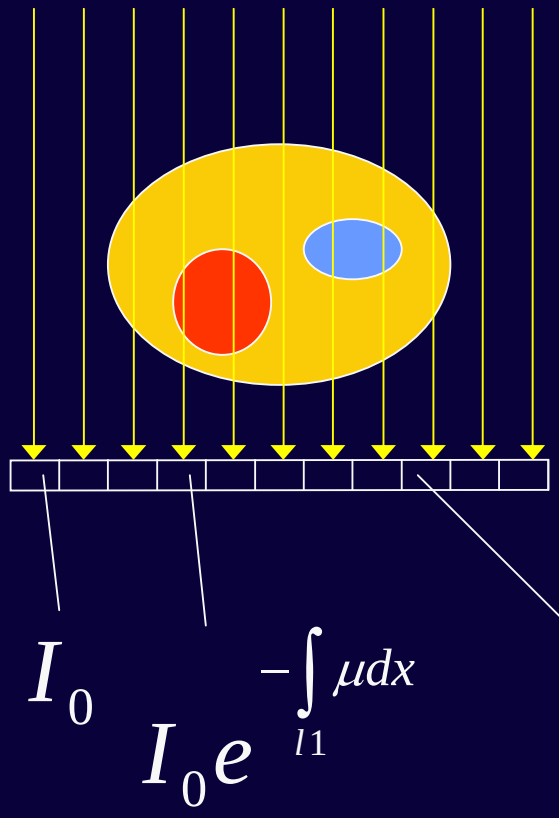


Source: University of Arkansas Medical School
http://anatomy.uams.edu/HTMLpages/anatomyhtml/xraythorax.html

How does it work?

- Laminar beam and laminar detector
- The object/patient is rotated in front of the beam
- During the rotation, planar images (projections) are acquired at different angles
- The matrix of acquired data is called SINOGRAM: each line of the sinogram corresponds to a projection at a given angle
- A map of the attenuation coefficients is reconstructed from the sinogram by means of proper algorithms

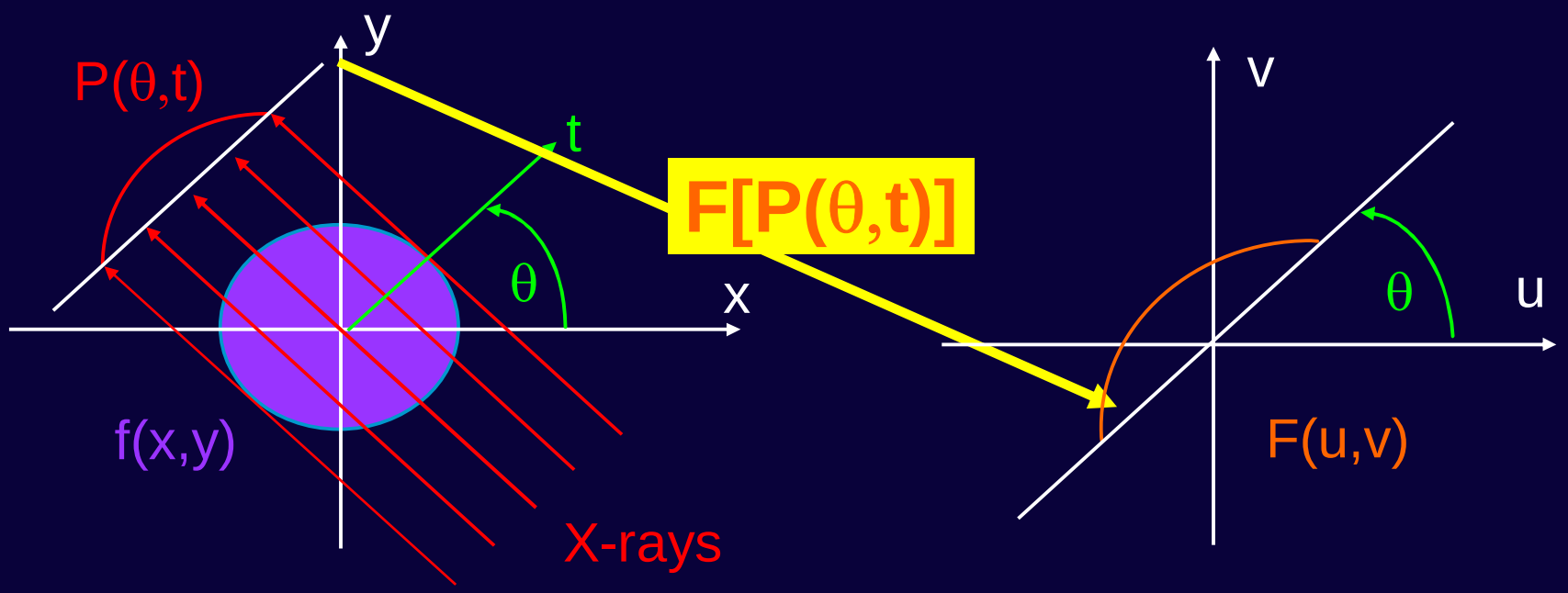
Image acquisition



- The line integral of the attenuation coefficient determines the attenuation along each X-ray path

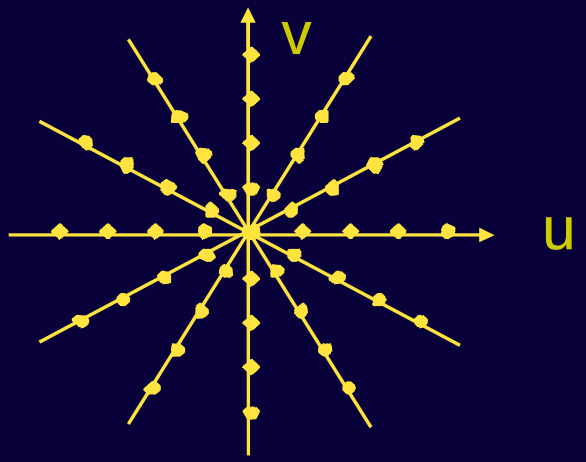
Image reconstruction: backprojection

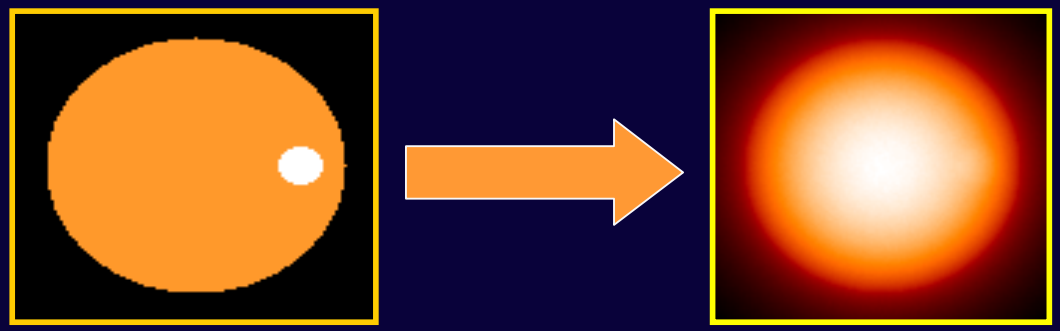
- Purpose: obtaining the distribution function f(x,y) given a complete set of projections P(θ,t)
- Fourier slice theorem: the FT of a projection P(θ,t) corresponds to a sampling of the FT of f(x,y) along a line tilted by an angle θ

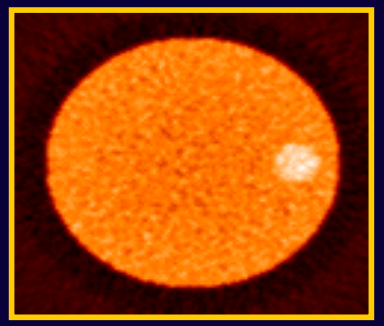


Filtered backprojection

- Each pixel of the matrix is reconstructed by summing up all projections crossing it
- But: oversampling for low frequencies!

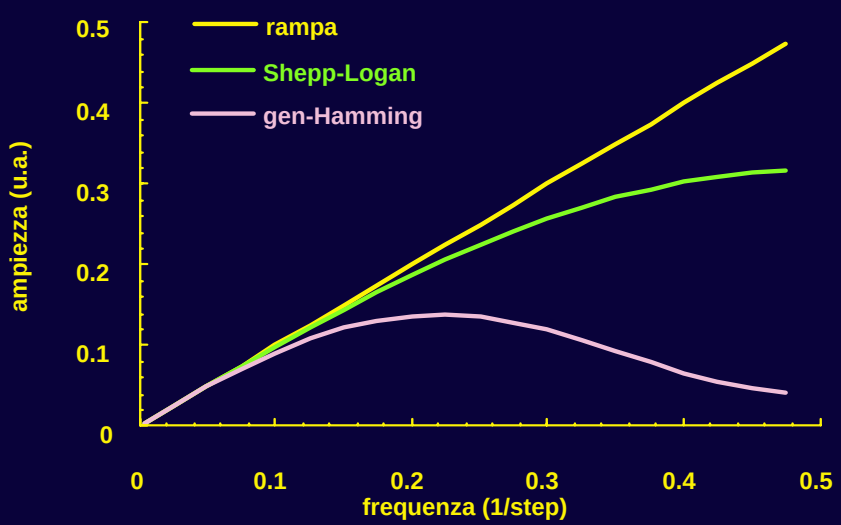


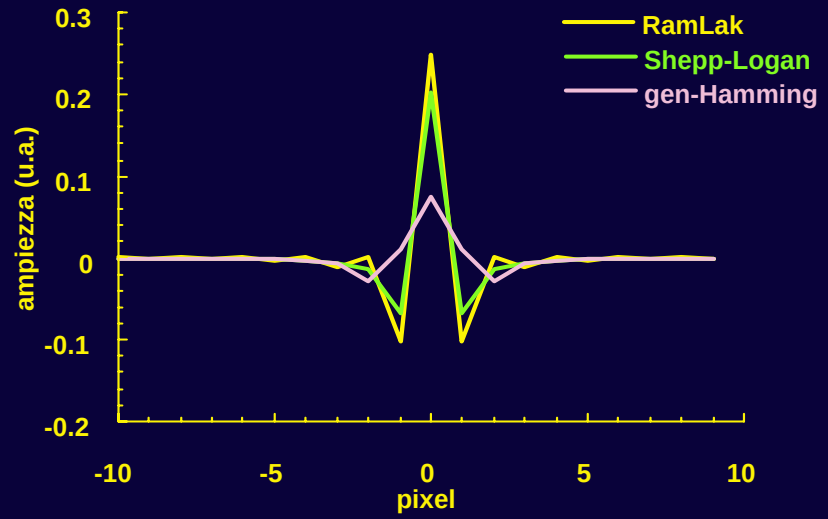




Filtering: each transformed projection is multiplied by a function reducing the contribution of low frequencies

Filtered backprojection

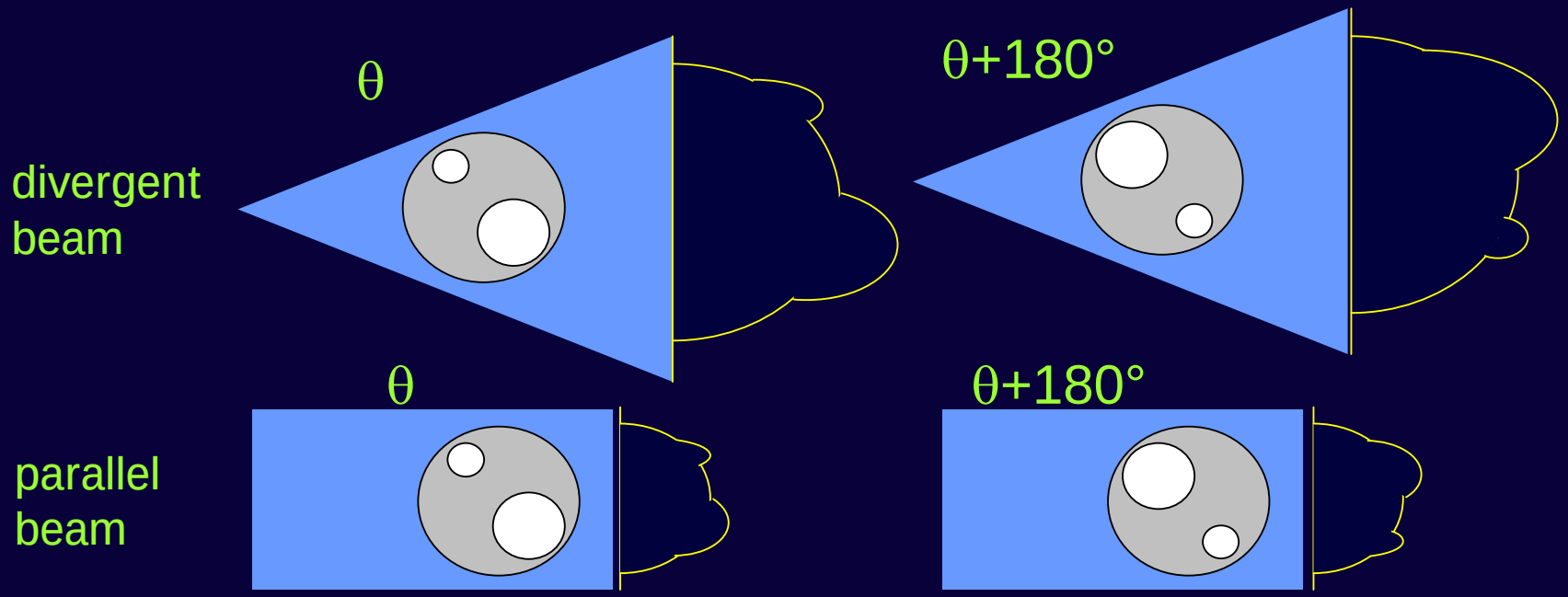




- Ramp filter (RamLak): enhancement of high frequencies → noise
- Gen-Hamming, Shepp-Logan: enhancement of intermediate frequencies
- Convolution theorem → convolution in the direct space as an alternative to multiplication in the Fourier space

The advantages of SR CT – I

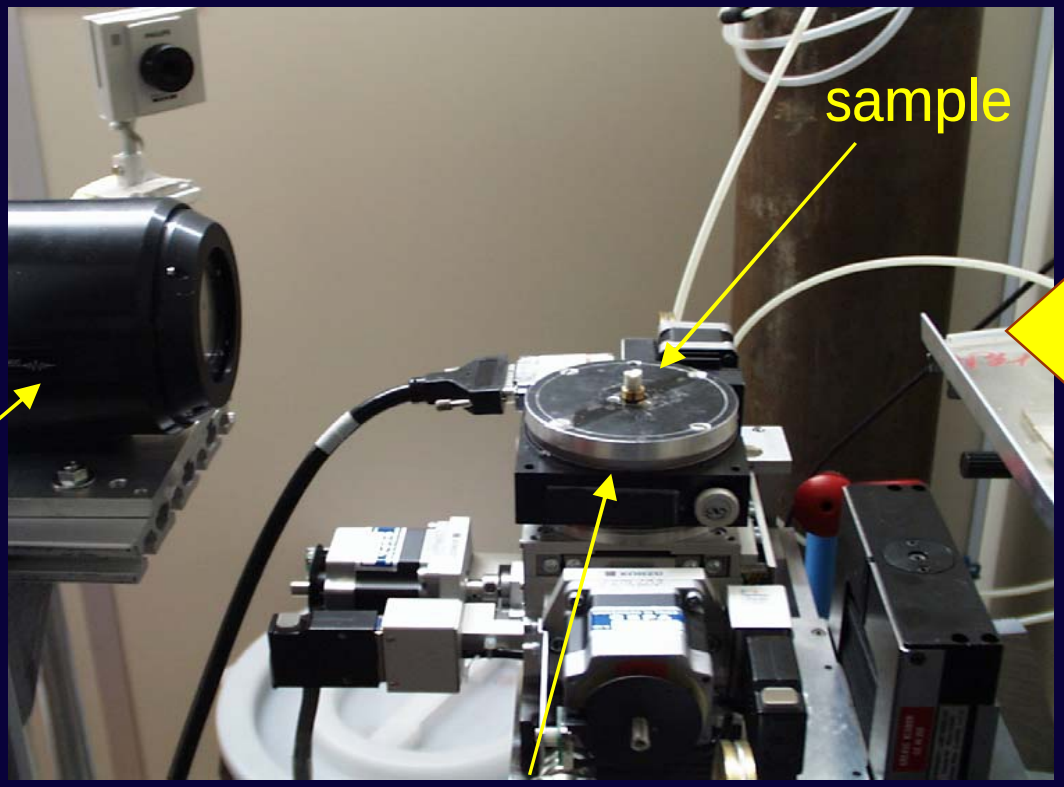
- Parallel beam:
  - an acquisition across 180 degrees provides all necessary information (lower dose – shorter acquisition time)
  - simplified reconstruction algorithms



The advantages of SR CT – II

- Monochromatic beam:
  - No beam hardening artifacts
  - Possibility of reconstructing true attenuation coefficients → tissue characterization

MicroCT at the SYRMEP beamline - I



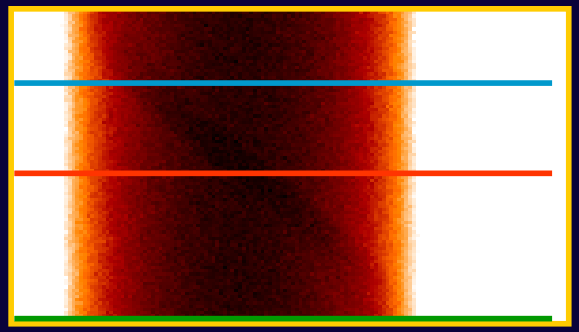
MicroCT at the SYRMEP beamline - II

- A projection = a 2048 * 300 matrix
- A height h is chosen
- A line at height h is extracted from each projection and a sinogram is formed

0 degrees

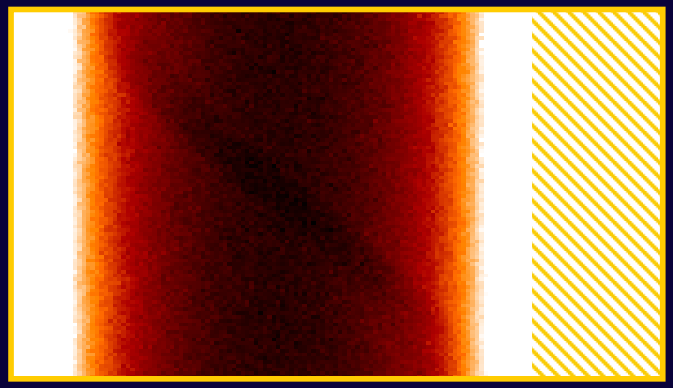
90 degrees

140 degrees



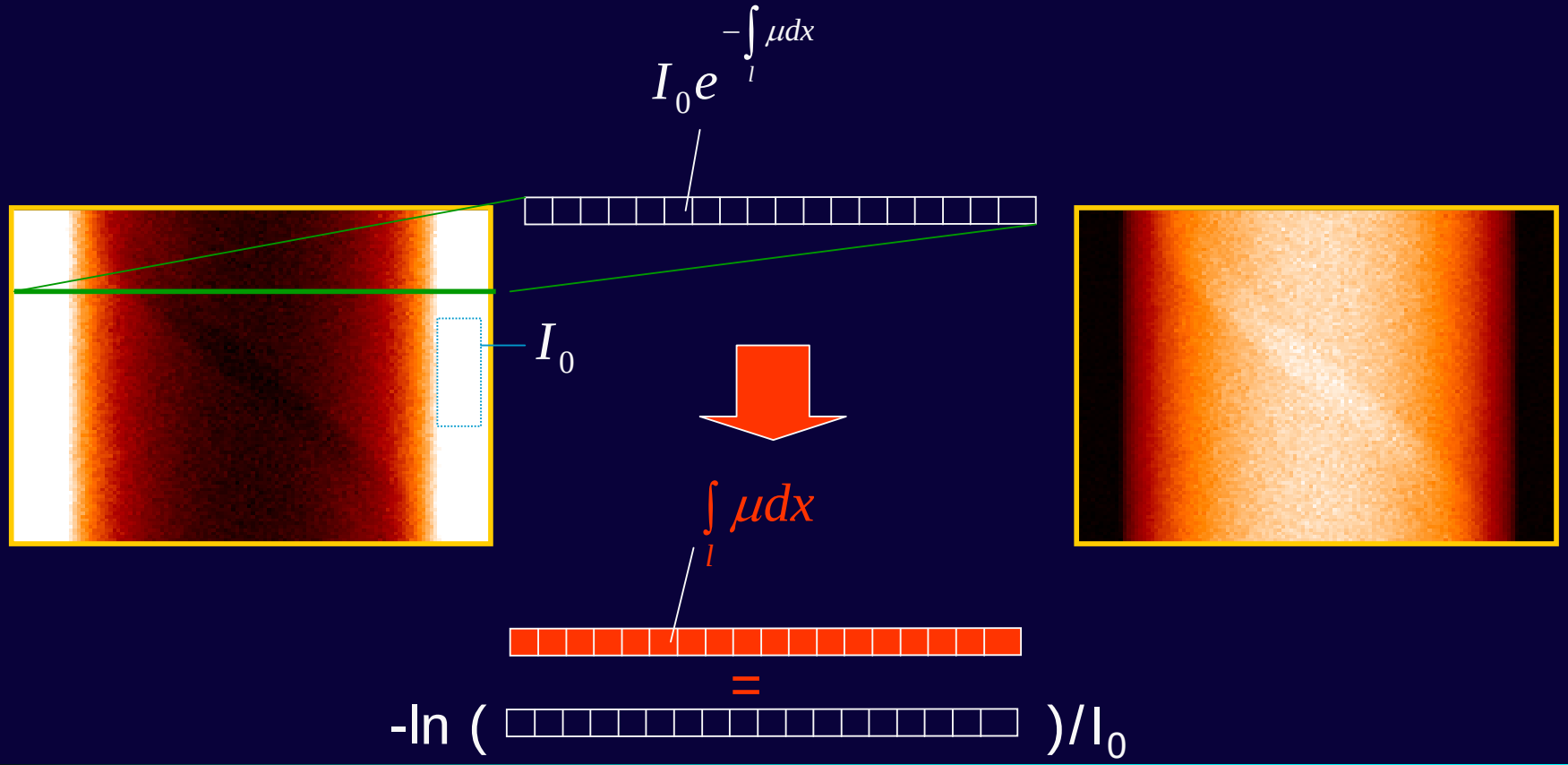
MicroCT at the SYRMEP beamline - III

- The sinogram is trimmed in order to have the center of rotation coincident to the center of the matrix



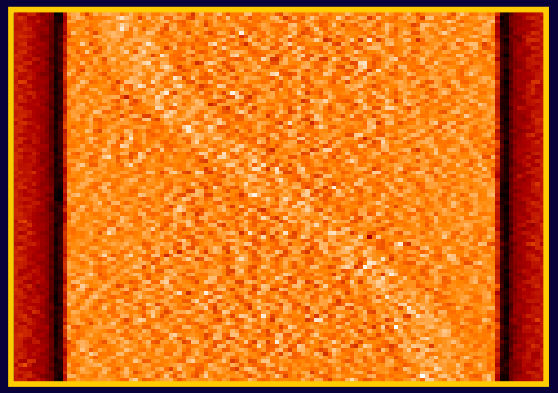
MicroCT at the SYRMEP beamline - IV

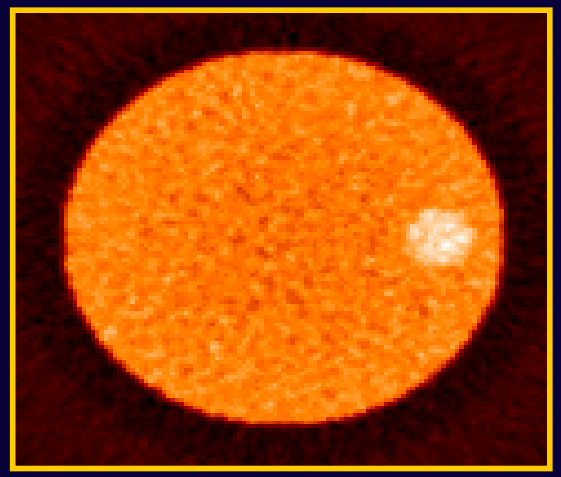
- The sinogram is transformed in order to obtain line integrals of the attenuation coefficients



MicroCT reconstructions at the SYRMEP beamline - V

- Each line of the logarithmic sinogram is filtered



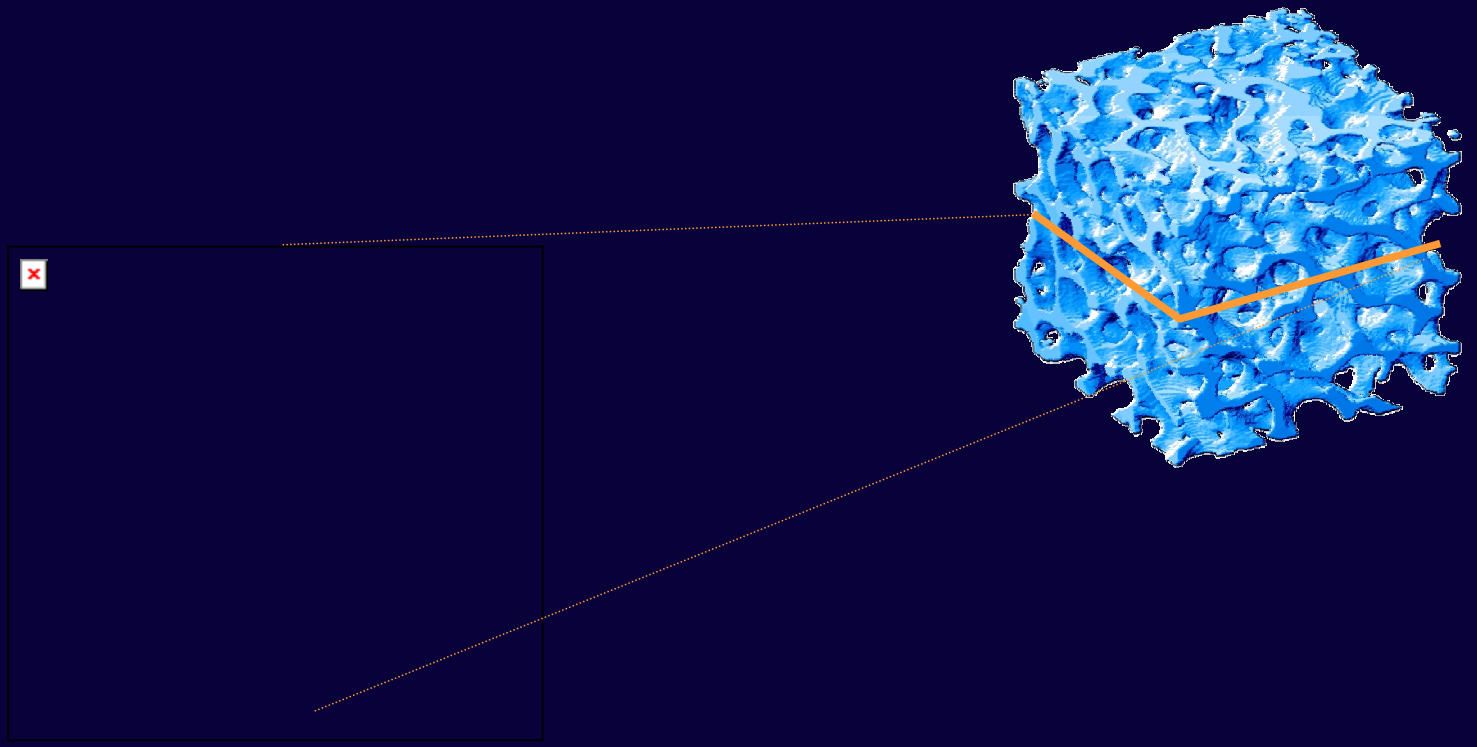


- The final image is obtained by means of a backprojection

Volume rendering

Volume rendering

- 2-d images are stacked
- The 3-d structure of the object is visualized



A possible application: sintered replicas of biological samples

- Why?
  - Tool for enhanced visualization
  - Used in mechanical tests to assess the bone architecture load bearing capabilities
    - Tests on biological samples cannot be repeated!
- How?
  - Built by rapid prototyping in a relatively homogeneous and well characterized material

Selected laser sintering

- The object is defined by means of a CAD file
- Layer Manufacturing Technology (LMT)
- Parts are manufacturing layer by layer from polyamide powder with a CO_2 laser
- Complex structures, such as the trabecular architecture, can be built