Preliminary Characterization of a Single Photon Counting System for CT Applications

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Detection system

Experimental setup

Tomographic reconstruction

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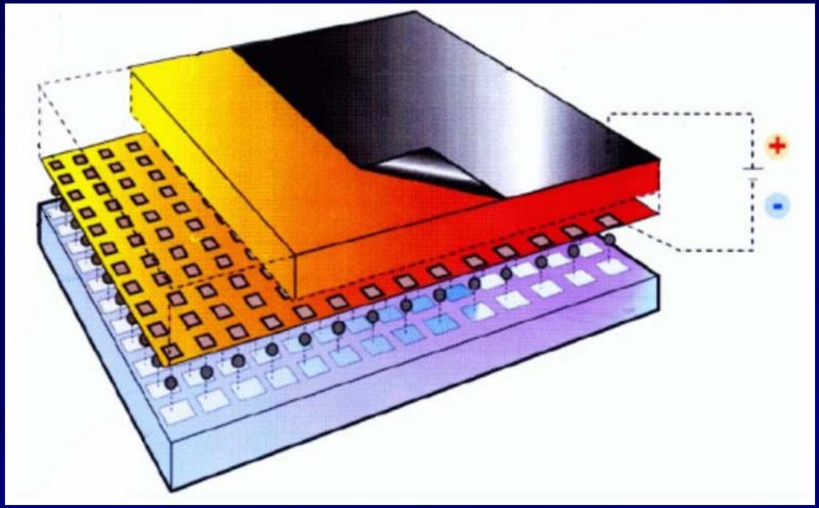

Based on the Medipix2 chip
Detector 1 mm Si
V_{dep} = 240 V
Produced by ITC-irst – Trento (Italy)
Bump-bonded by VTT (Finland)

- 256 x 256 square pixel matrix (size 55 µm)
- Spatial resolution @ 10% MTF: 17 lp/mm
- Total active area: 14 x 14 mm^2
- 13 bit pixel counter
- Max. count rate per pixel 1 MHz
- Electronic noise (sigma) 105 e^-
- Window threshold discriminator (low and high level)
- Radiation tolerance <200 krad (10 keV X-ray)

The MicroCT prototype

Experimental setup

Tomographic reconstruction

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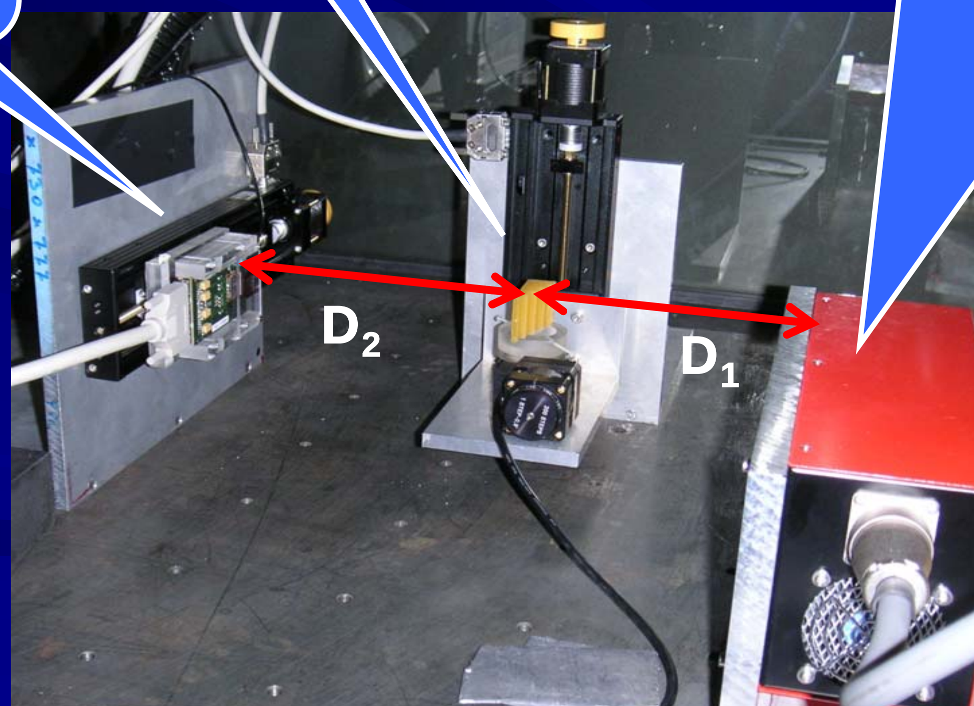
X-ray source: Hamamatsu 60KVFMX

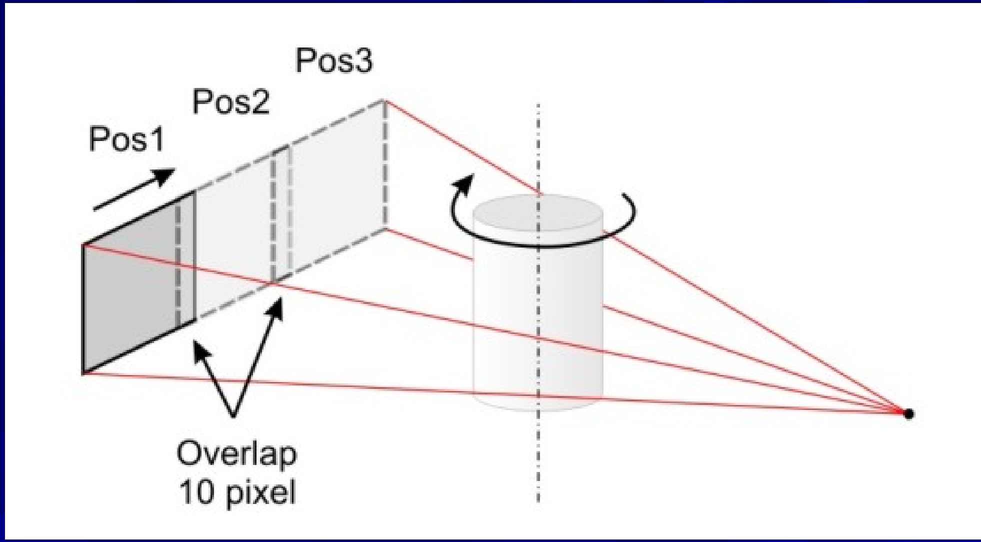
- Tungsten anode, Be window (150 μm)
- 0 up to 60 kV voltage
- 10 W power
- 20 μm focus size

Rotating phantom

Detector + Traslation stage



Tomographic acquisition



Experimental setup

Tomographic reconstruction

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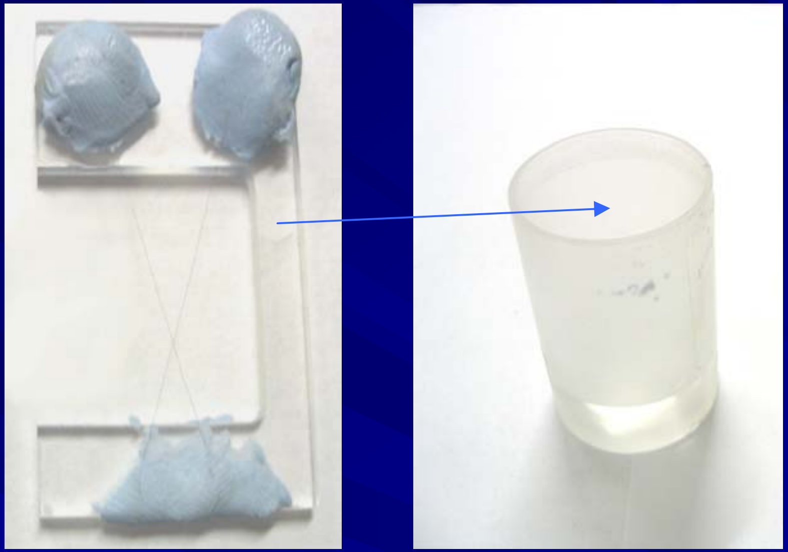
Conclusions

- Linear scanning is required to enlarge the FoV
- The cone-angle is small (~ 2°), so fan-beam reconstruction is suitable
- Typical acquisition parameters:
  - 30 kVp, 0.5 mAs/view
  - 1 mm Al filtration
  - 480 angles over 360°
  - Magnification factor ranging from 1.2 to 2.9

Phantom for PSF measurement



- A tungsten wire (20 micron)
- Plastic cylinder empty or filled with water
- 3 cm outer diameter, 1 mm wall thickness

Tomographic reconstruction

Experimental setup

Tomographic reconstruction

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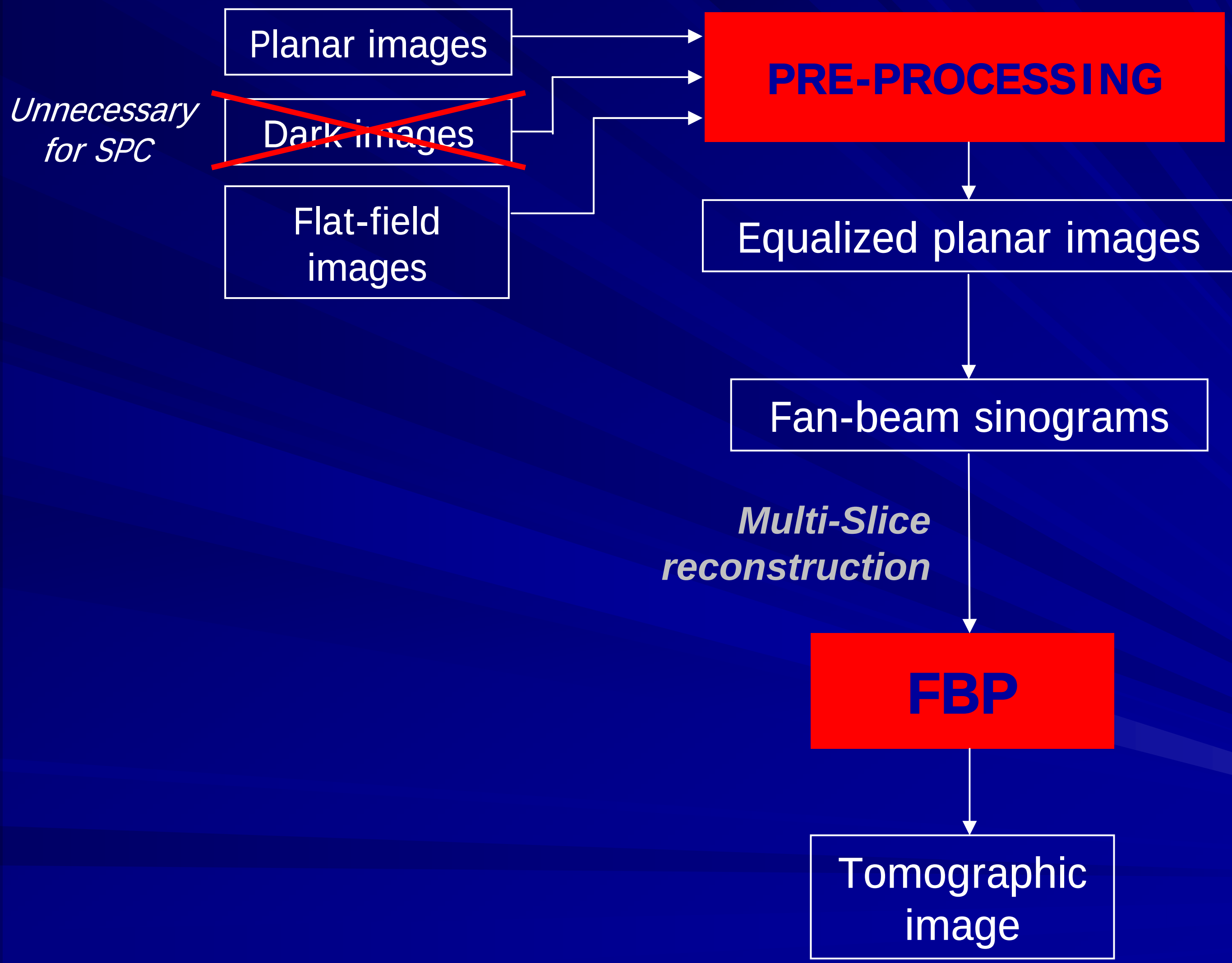

Spatial resolution: modeling the PSF

- We model the in-plane PSF as a 2D Gaussian function of width σ_{PSF}:

$$\sigma_{\mathrm{PSF}} = \sqrt{\left(\frac{1}{m}\sigma_{\mathrm{det}}\right)^2 + \left[\left(1-\frac{1}{m}\right)\sigma_{\mathrm{foc}}\right]^2 + \left(\frac{1}{m}\sigma_{\mathrm{alg}}\right)^2}$$

where

$$m = \frac{\mathrm{D}_1 + \mathrm{D}_2}{\mathrm{D}_1}$$

is the magnification factor.

- The resulting MTF is a Gaussian of width σ_{MTF}:

$$\sigma_{\mathrm{MTF}} = \frac{1}{2\pi\sigma_{\mathrm{PSF}}} \quad ;$$

$$f_{10\%} = \sigma_{\mathrm{MTF}}\sqrt{2\ln 10} \quad .$$

PSF components

Experimental setup

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- σ_{det} and σ_{foc} were measured with the slit technique (30 kVp, 0.25 mA):

  σ_{det} = 22.5 μm (± 5%)

  σ_{foc} = 9 ± 2 μm

- The blurring due to the linear interpolation involved in the reconstruction process can be modeled as follows:

  $MTF_{interp} = |sinc^2(f \cdot \Delta x)|$, Δx = reconstruction pixel size;

corresponding to a triangle convolution kernel with FWHM = Δx.

- Approximating the triangle function with a gaussian, we can write:

  $\sigma_{interp} \approx \Delta x / 2.35$.

- If ramp filter is used, no further blurring is introduced by the reconstruction algorithm:

  $\sigma_{alg} = \sigma_{interp}$ (for FBP reconstruction with ramp filter)

MTF measurement

Experimental setup

Tomographic reconstruction

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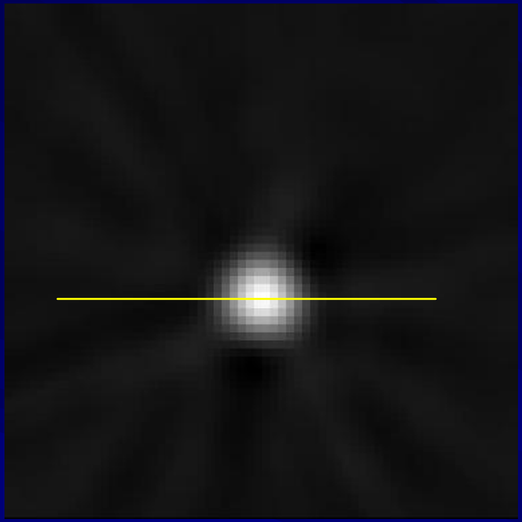
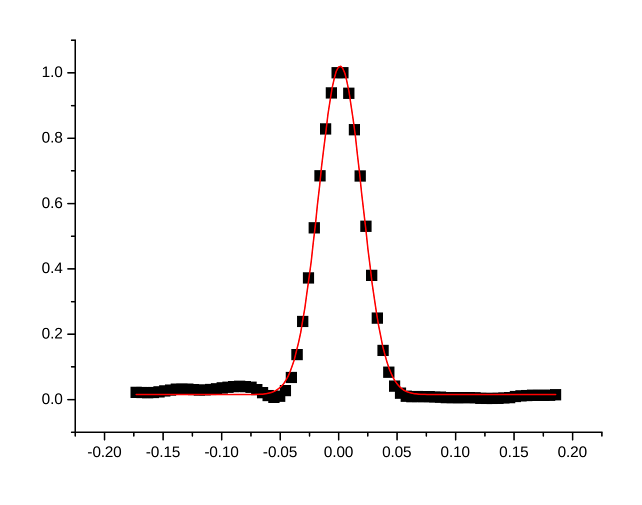
Reconstruction of W wire (PSF)

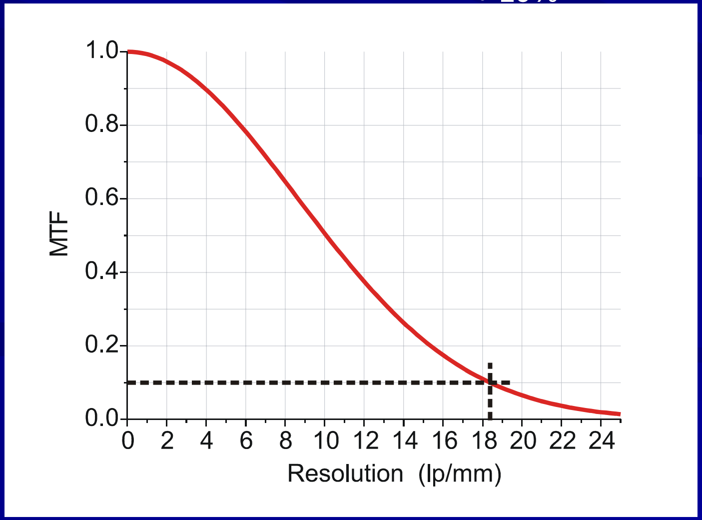


Gaussian fit of the profile



FFT

Determination of $f_{10\%}$



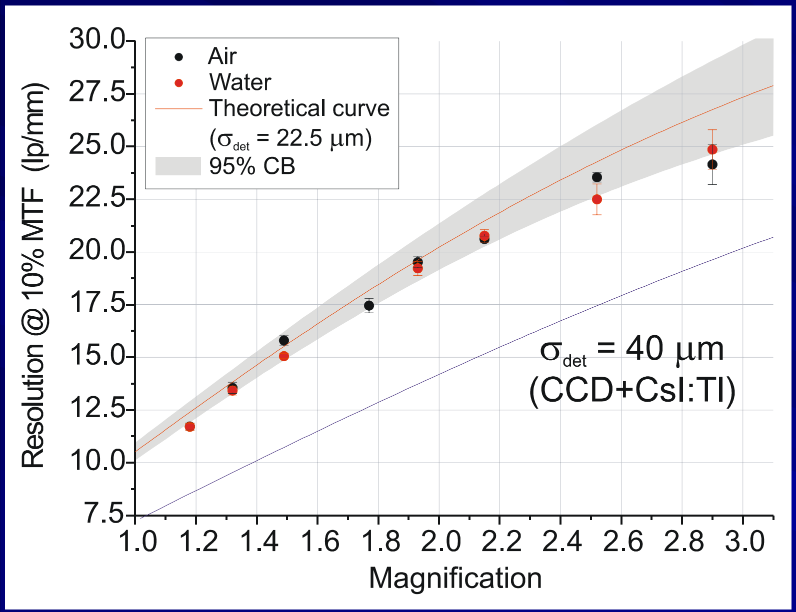
Spatial resolution of the tomographic system

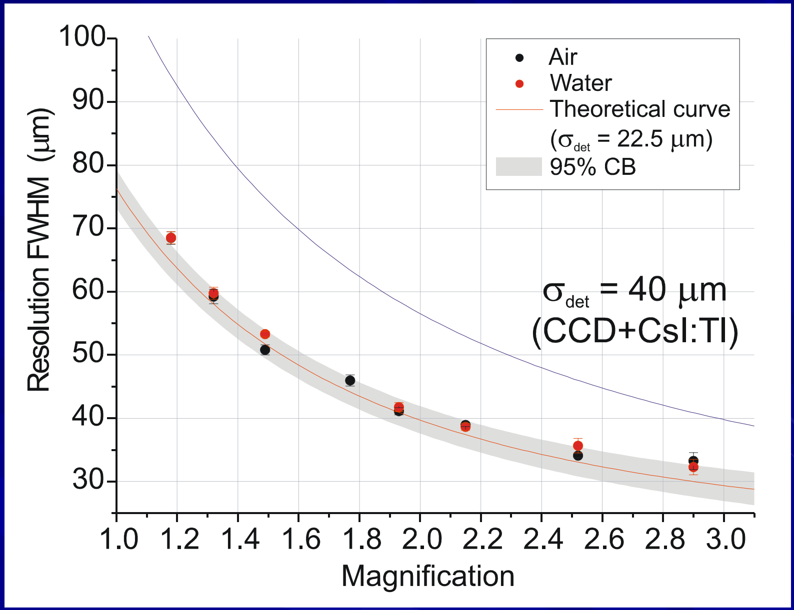
Experimental setup

Tomographic reconstruction

Results

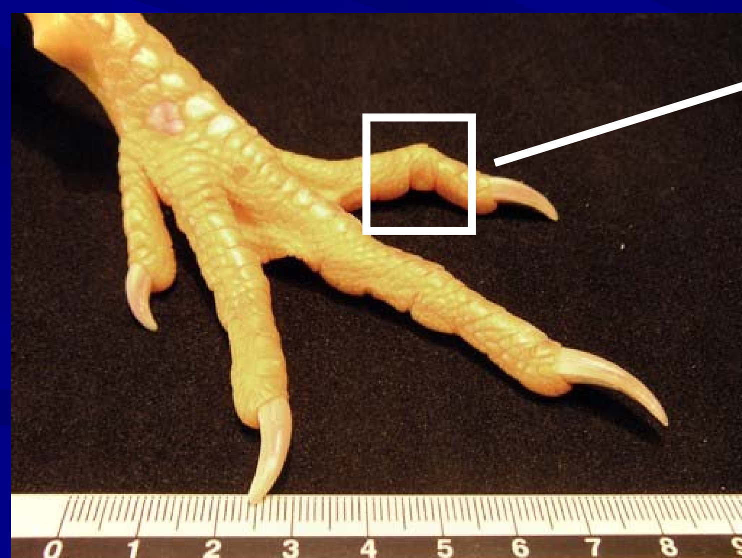
Conclusions

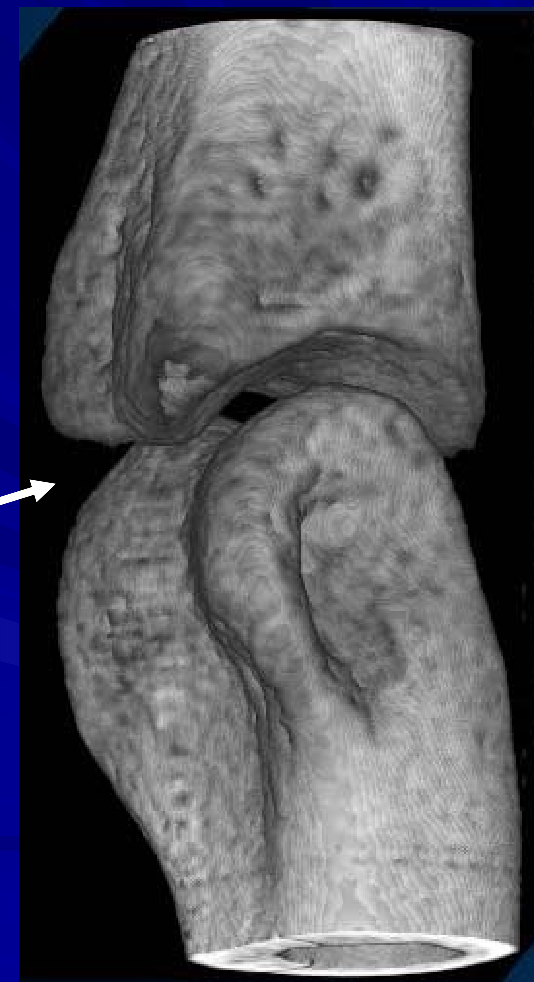




Application:
Bone studies on small animals

- We have imaged the finger joint of a chicken
- 60 kVp, 0.3 mAs/view, 1 mm Al filter
  Energy window: 12-15 keV
- The system is able to resolve the internal structure of bones





Application:
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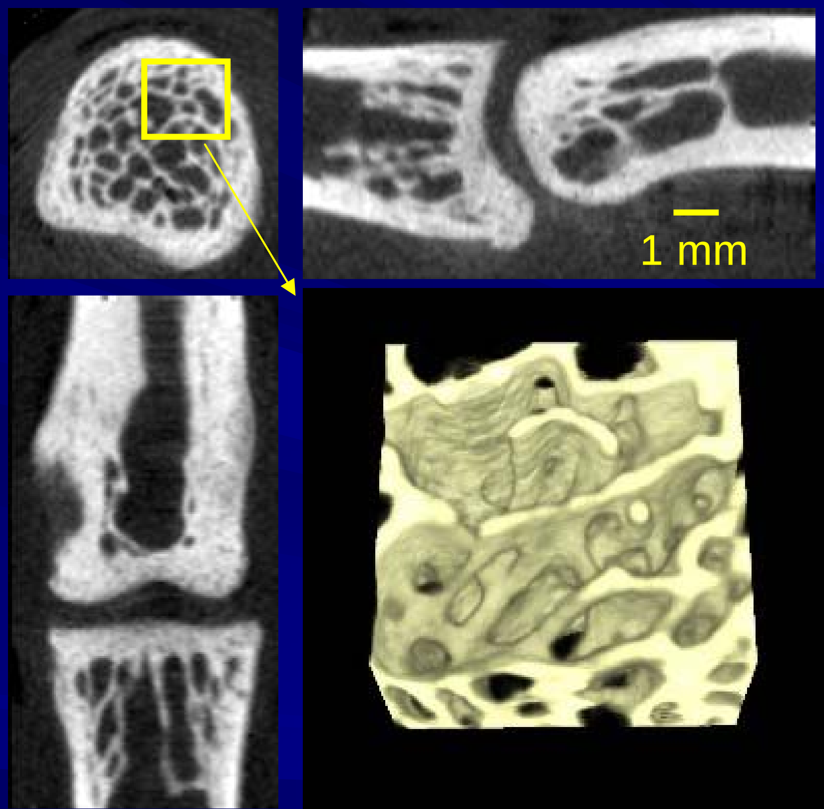
Transaxial

Sagittal



Coronal

Conclusions and future work

Experimental setup

Tomographic reconstruction

Results

Conclusions

• We have characterized a MicroCT scanner prototype based on a Single Photon Counting detection system in terms of spatial resolution.

• According to the theory, we obtained resolutions ranging from 11 to 24 lp/mm, for magnification factors ranging from 1.1 to 2.9.

• The system is suitable for high resolution studies on small animals (e.g. bone microstructure).

• We are working on special applications allowed by a Single Photon Counting system (e.g. Dual Energy CT, energy windowing, ecc...).