

Optimizing Your Control File Settings

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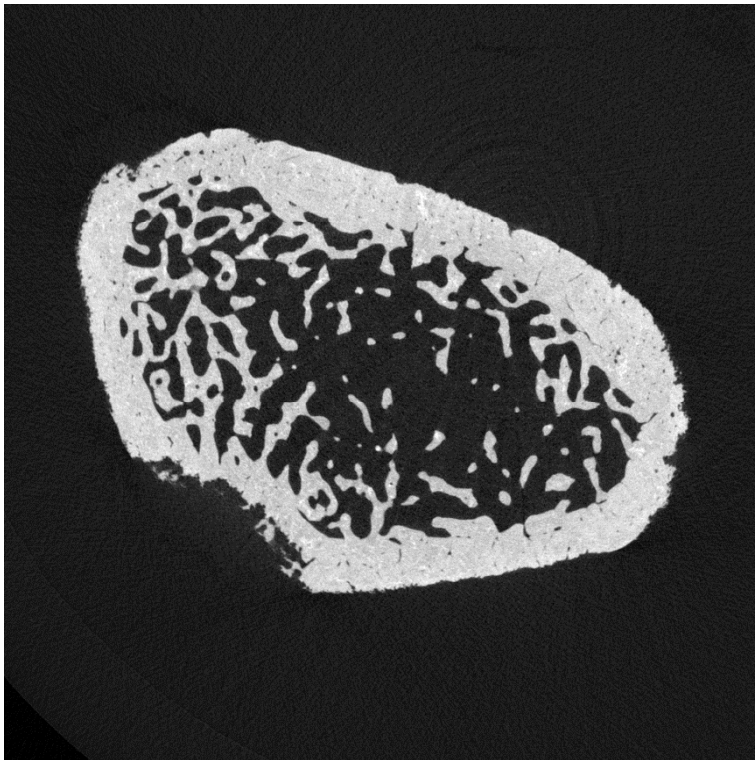
Motivation

- Optimize control file settings with respect to
 - ✓ Resolution
 - ✓ Contrast (separability of objects)
 - ✓ Scan time
 - ✓ Artifacts
- No settings optimize for all aspects

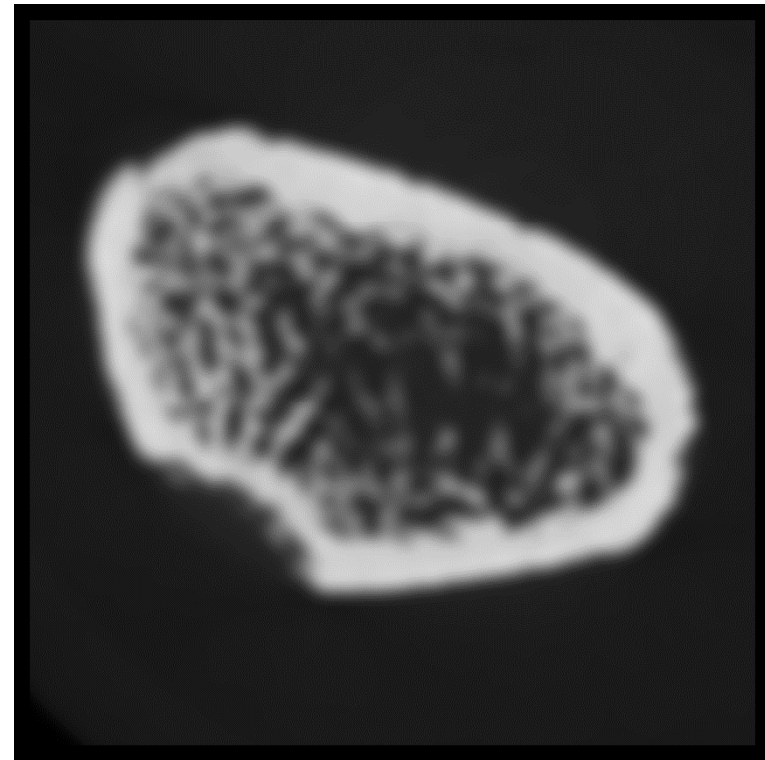


High and Low Resolution

- Rat femur



Resolution 7 μm

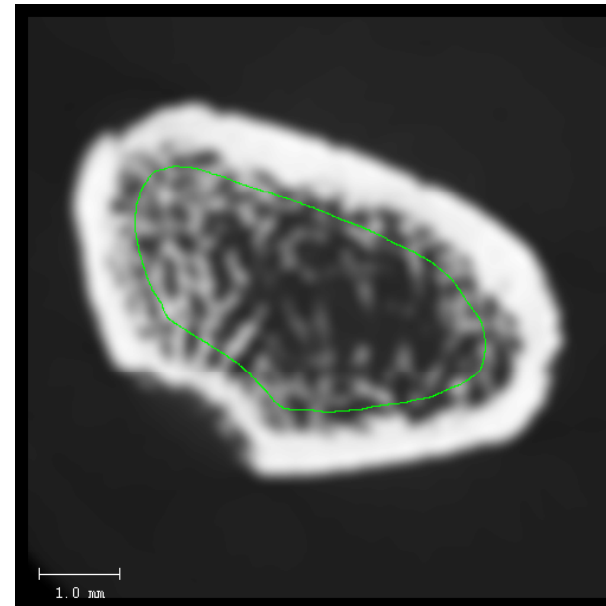
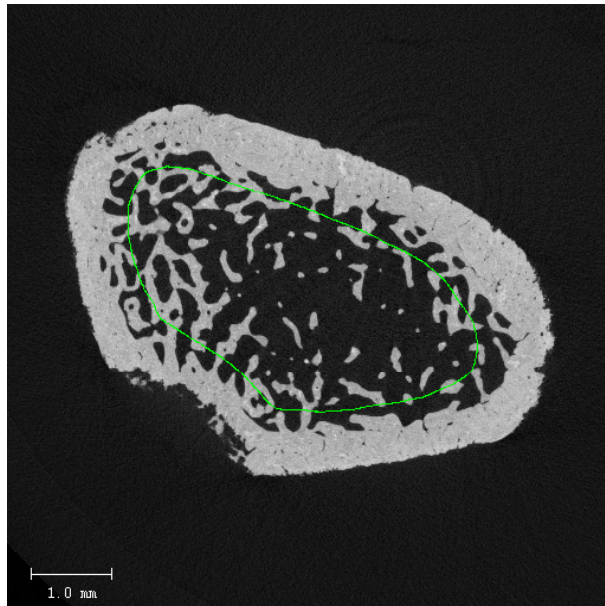


Resolution 168 μm

SW/3



High and Low Resolution



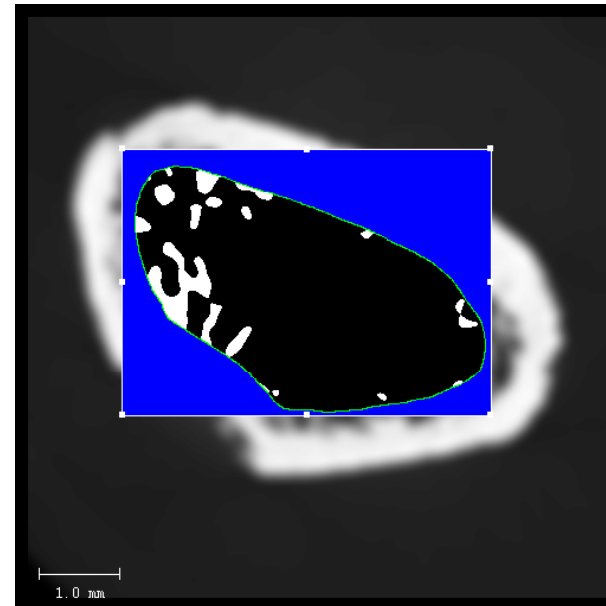
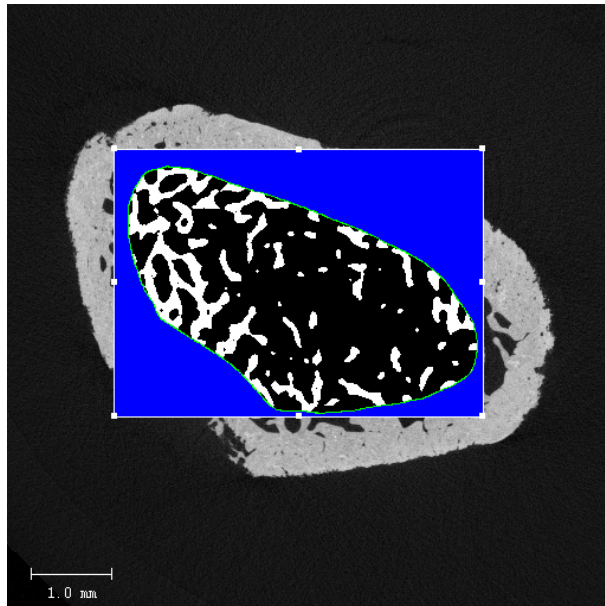
267.3

BMD [mgHA/ccm]

266.8



High and Low Resolution



267.3

3.46

BMD [mgHA/ccm]

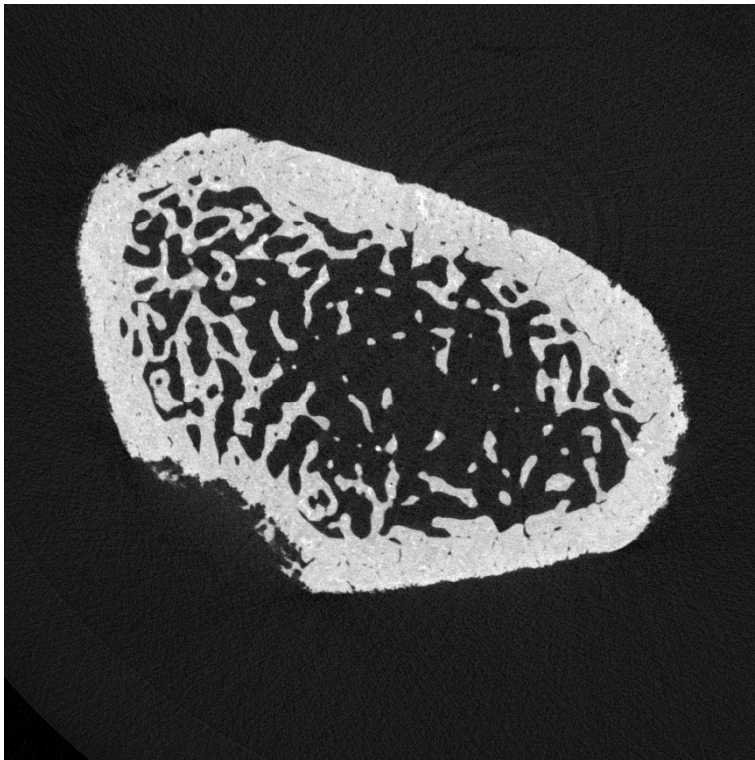
TB.N [1/mm]

266.8

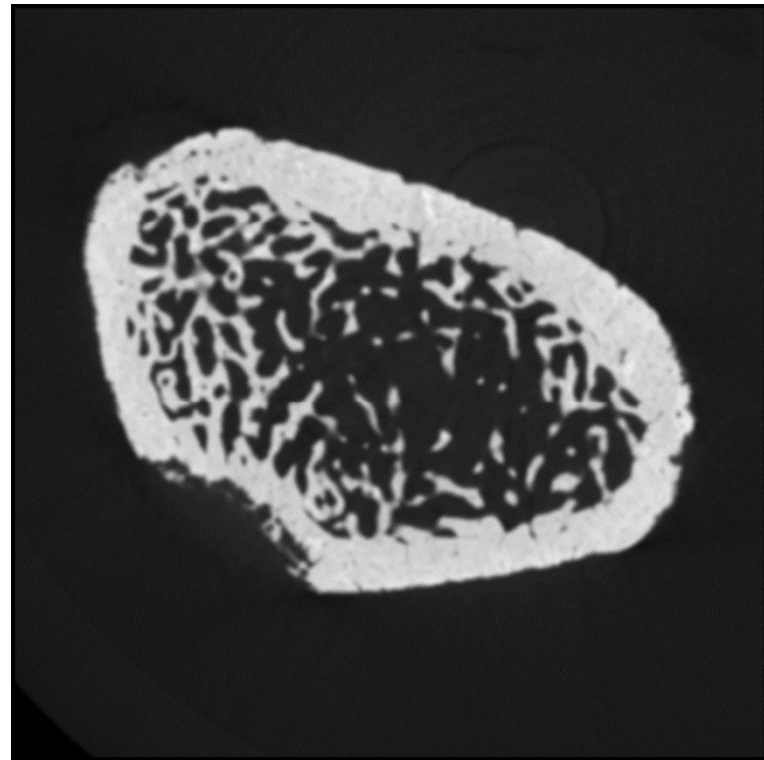
0.98



High and Low Resolution



Resolution 7 μm

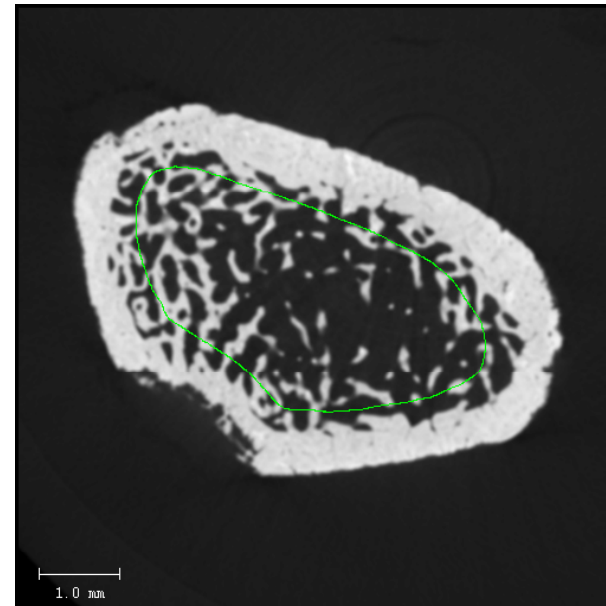
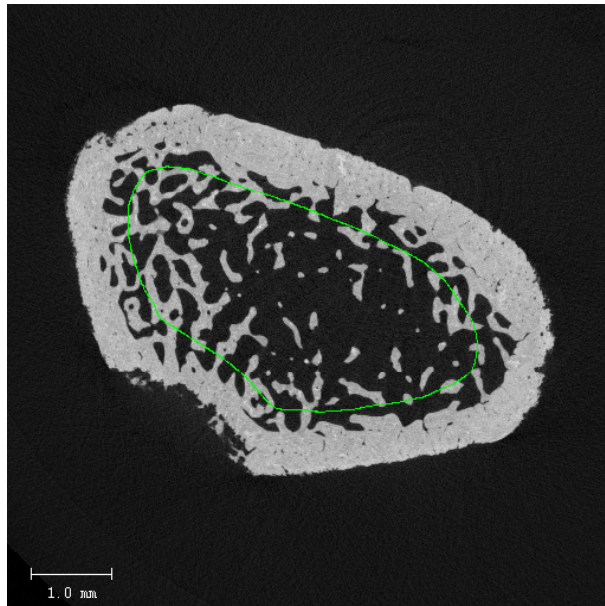


Resolution 42 μm

SW/6



High and Low Resolution



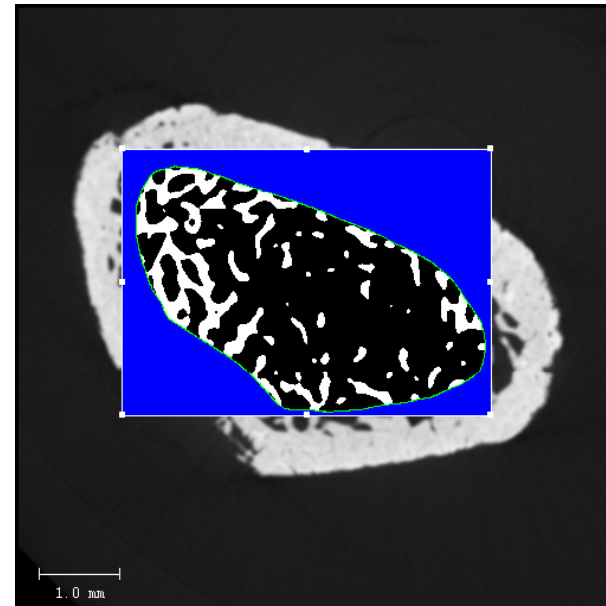
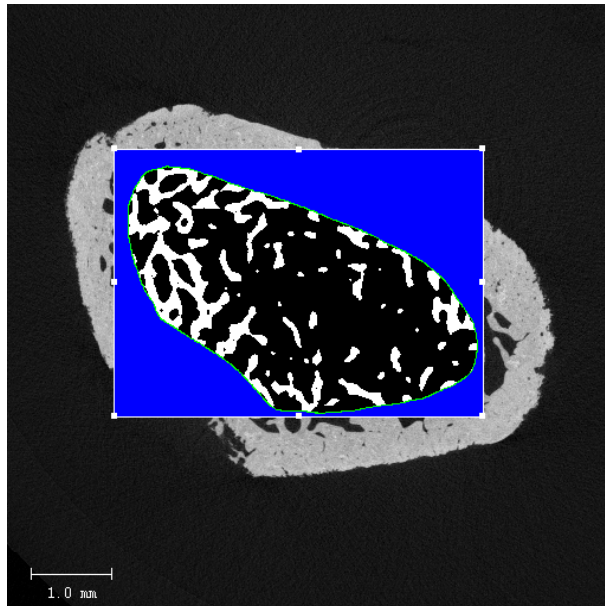
267.3

BMD [mgHA/ccm]

267.1



High and Low Resolution



267.3

3.46

BMD [mgHA/ccm]

TB.N [1/mm]

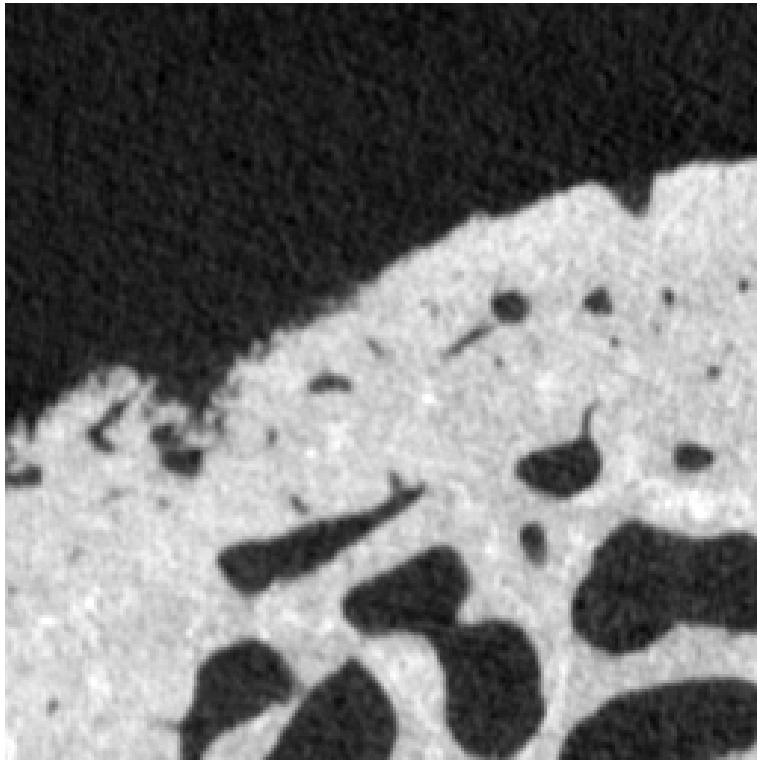
267.1

3.30

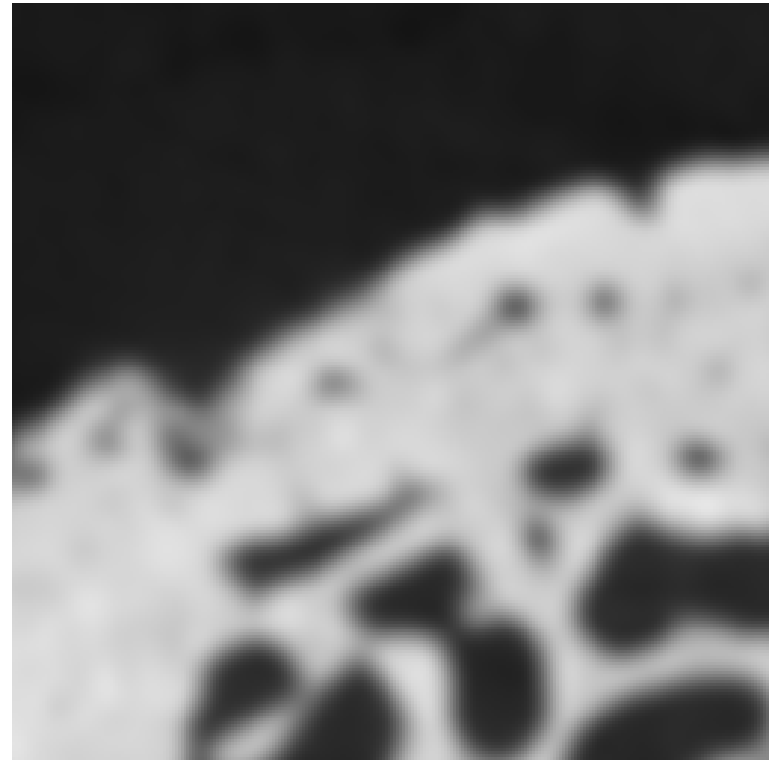


High and Low Resolution

- Pores in Cortex



Resolution 7 μm



Resolution 42 μm

SW/9



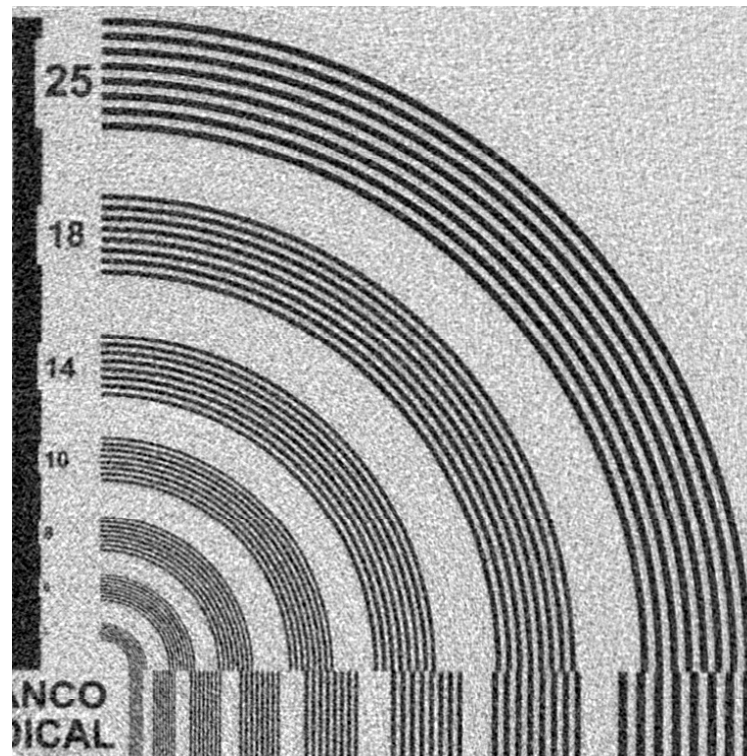
Resolution

- Is needed
 - ✓ To visualize & quantify small structures
- Is not needed
 - ✓ To measure mean density of a large volume
- The optimal resolution depends on the project!
 - ✓ High resolution scans require
 - Longer scan time
 - Longer reconstruction time
 - Higher dose
 - Longer evaluation time ...



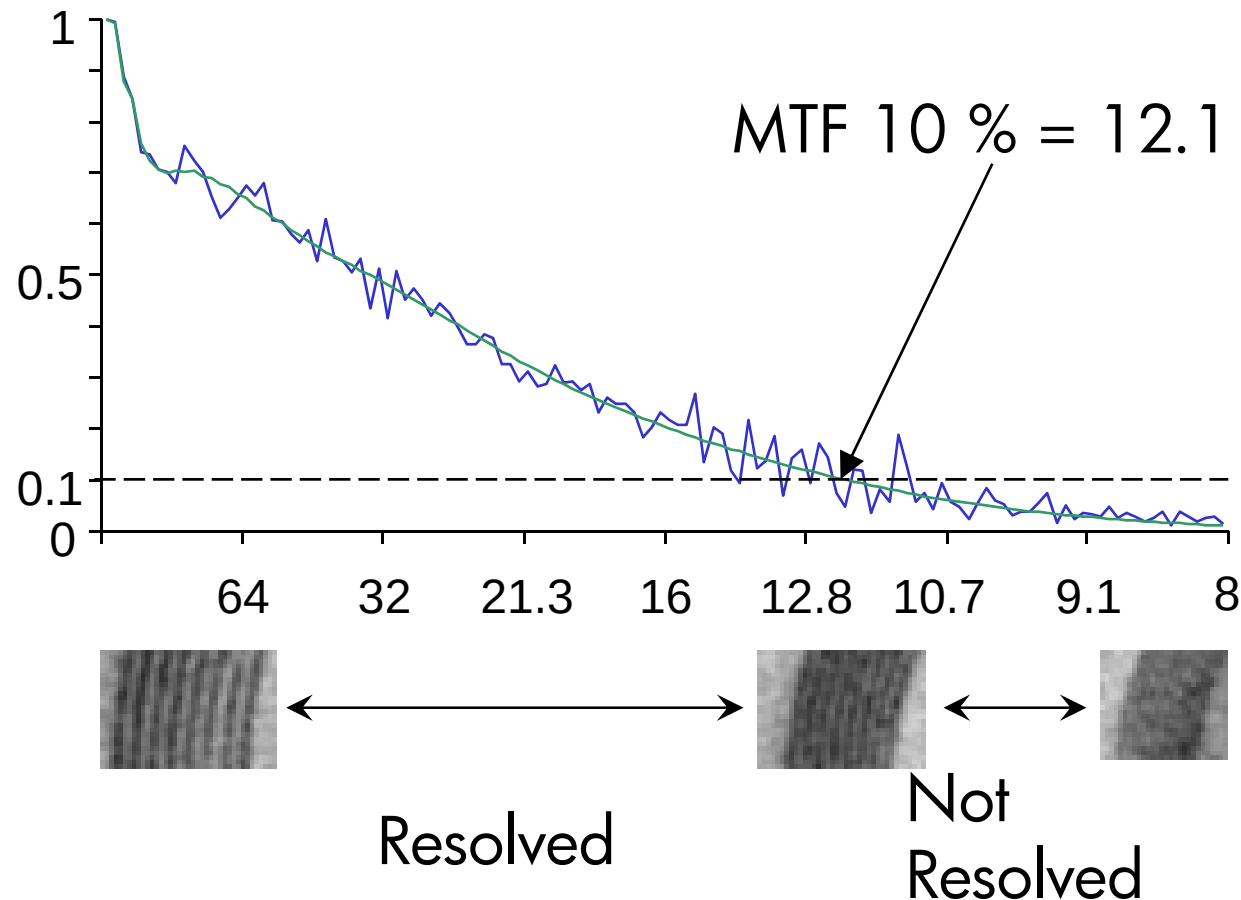
Resolution – Practical Definition

- Distance between objects (or cavities) at which they can still be identified as independent from each other



Resolution – Technical Definition

- 10 % MTF value derived from edge spread function



Resolution

- 10% MTF value
 - ✓ Cannot be smaller than the image voxel size
 - ✓ Is not the image voxel size (nominal resolution)
- High resolution images require high resolution projections
- More details @ www.scanco.ch
 - ✓ User meeting 2008
 - ✓ Presentation Image Quality



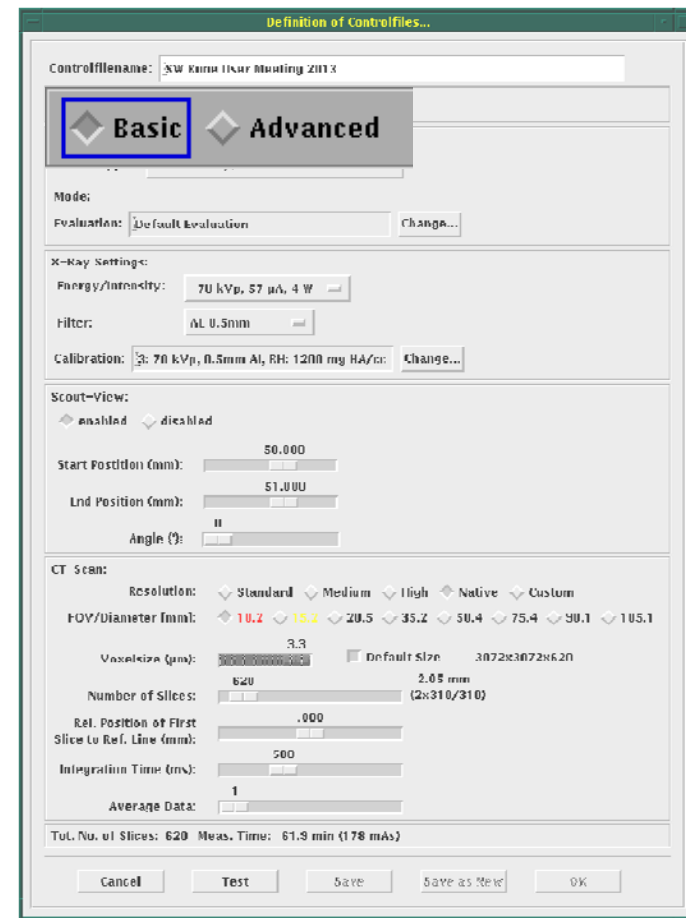
Demo Images

- μ CT 100
- Measurement program V6.3 (released)



Control File Modes

- Basic mode
 - ✓ Predefined settings
 - ✓ Easy to use
- Advanced mode
 - ✓ User defined settings
 - ✓ Requires some knowledge



Sample Holder

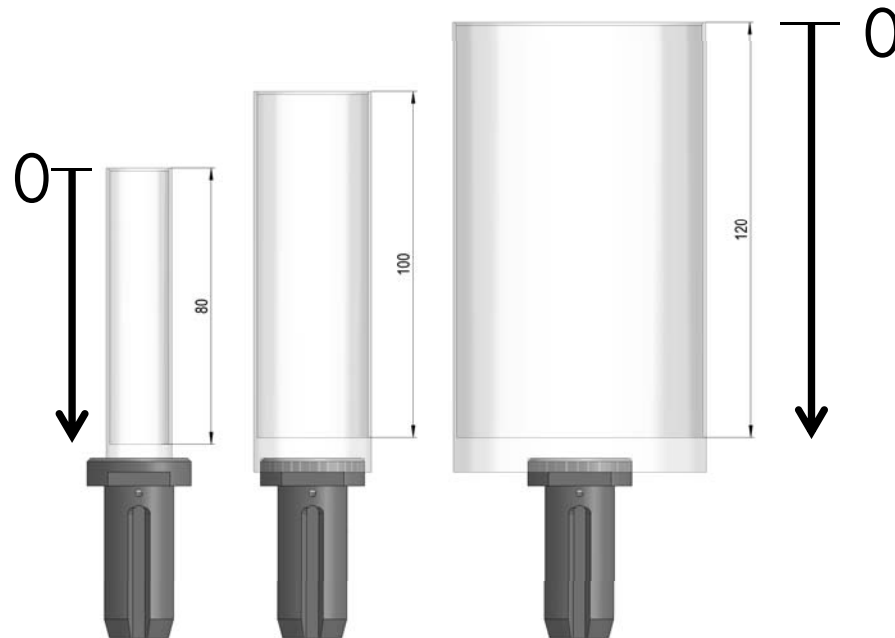
- Choose correct holder
- Reference 0 @ top
- Sample must fit

General:

Holder Type:

Mode:

Evaluation:



FOV/Diameter

General:

Holder Type: U50824, ø 19mm x H 84mm

Mode:

Evaluation: Default Evaluation Change...

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☐ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (µm): 6.6 ☐ Default Size 3072x3072x310

Number of Slices: 310 2.05 mm
(2x155/309)

Rel. Position of First Slice to Ref. Line (mm): .000

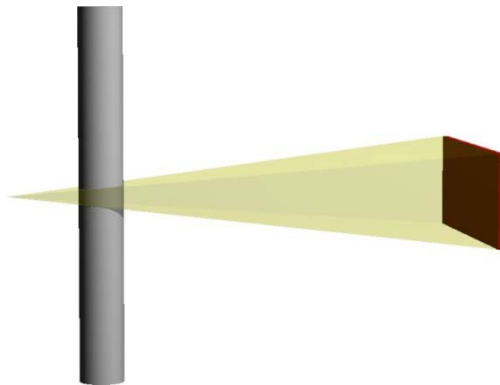
Integration Time (ms): 500

Average Data: 1

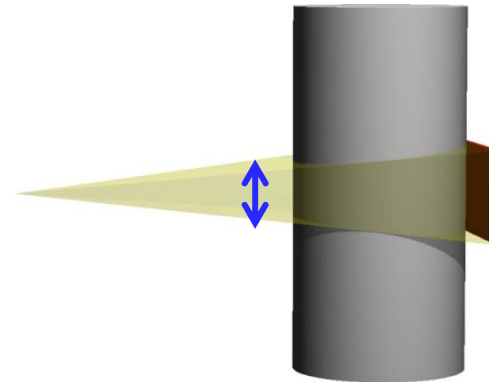


FOV/Diameter

- Determines
 - ✓ Sample distance to source
 - ✓ Geometrical magnification
 - ✓ Stack height



FOV 10 mm
Magnification: ~14
Stack height: 1.0 mm

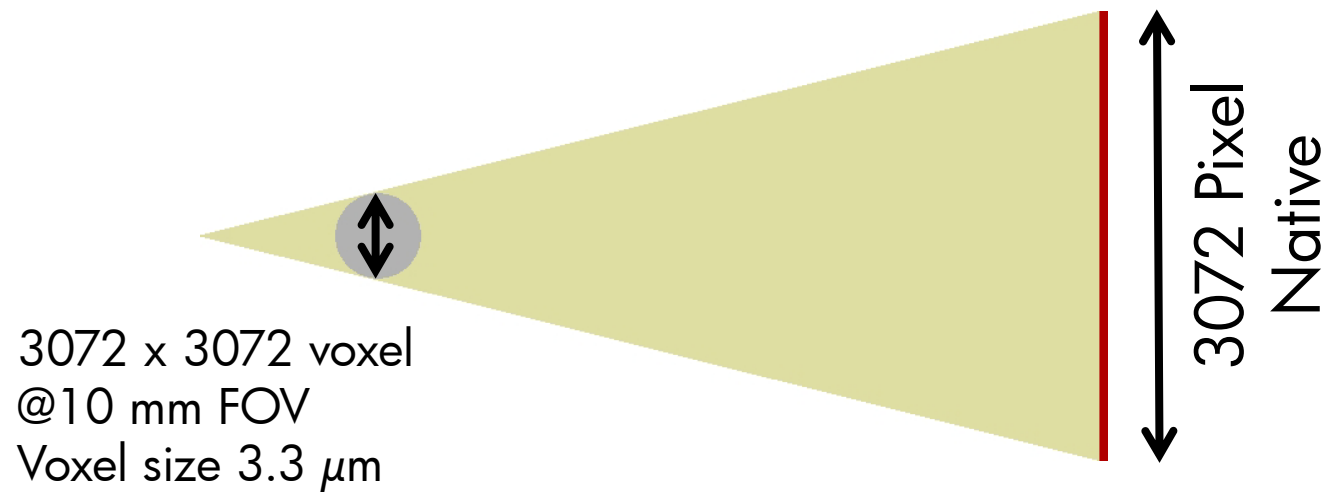


FOV 105 mm
Magnification: ~1.3
Stack height: 10.5 mm



FOV/Diameter

- Default voxel size



CT-Scan:

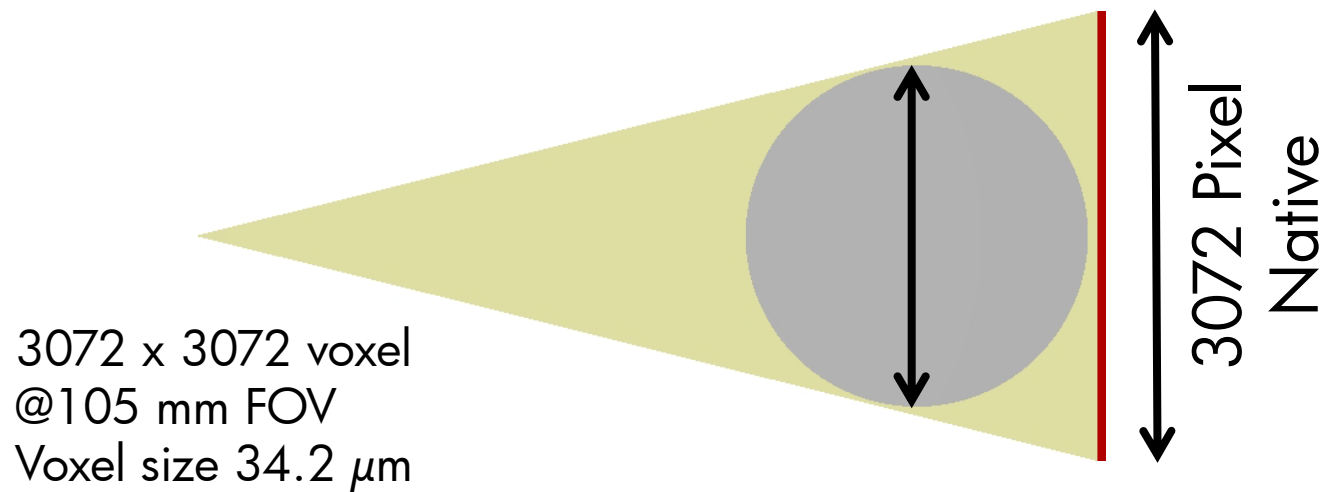
Resolution: ☐ Standard ☐ Medium ☐ High ☒ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (μm): ☐ Default Size 3072x3072x620

FOV/Diameter

- Default voxel size



CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☒ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (μm): ☐ Default Size 3072x3072x309

FOV/Diameter

- Default Voxel Size
 - ✓ Roughly: one voxel is projected onto one detector pixel
 - ✓ Objects (points, lines) smaller than one default voxel cannot be distinguished on the detector
- Default voxel size is roughly a boundary for the 10% MTF value

μ CT 100
3.3 μ m voxel @10 mm FOV
10% MTF $\sim$ 3.6 μ m



FOV/Diameter – Colors

General:

Holder Type: U50824, ø 19mm x H 84mm

Mode:

Evaluation: Default Evaluation Change...

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☐ Custom

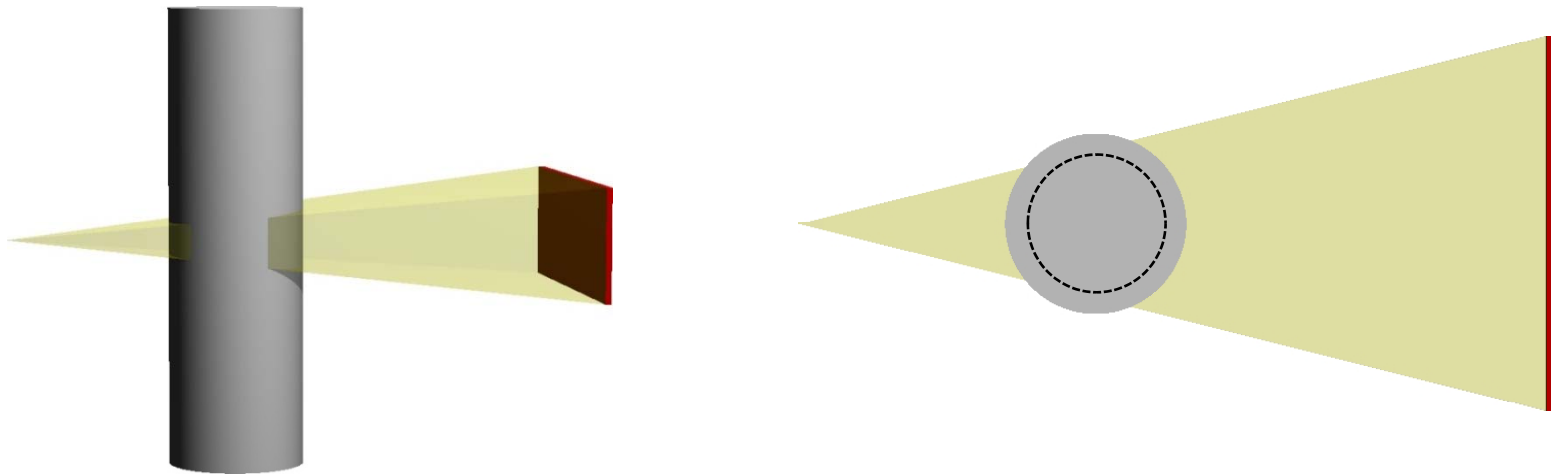
FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☒ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

- Check colors @ FOV/Diameter
 - ✓ Black: Possible
 - ✓ Red: Not possible, sample would crash into scanner
 - ✓ Yellow: Possible, be careful (local tomography)



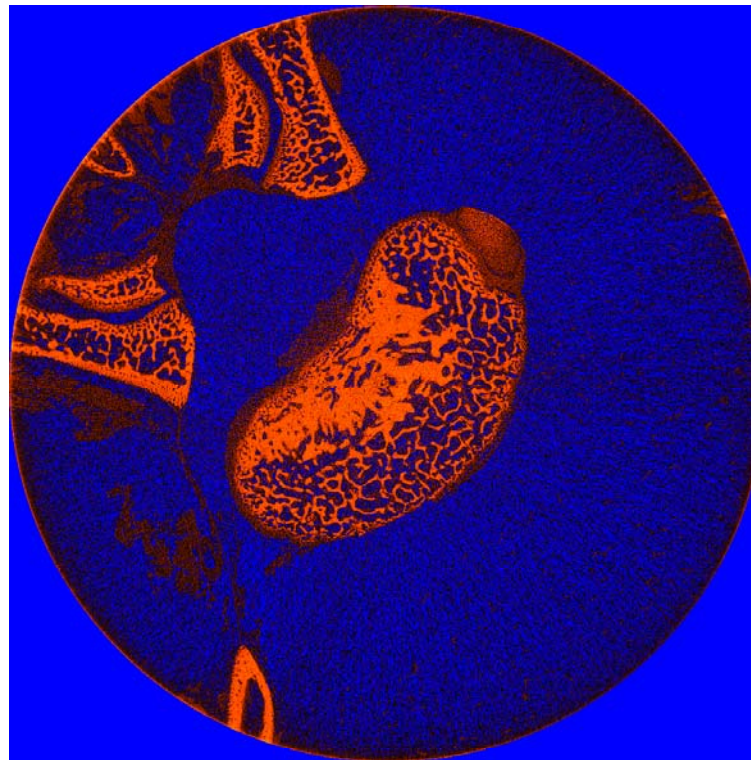
FOV/Diameter – Local Tomography

- Sample fits into geometrical position but not into the cone beam
- Higher resolution compared to standard position
- Creates artifacts depending on the sample
- Density values might be wrong



FOV/Diameter – Local Tomography

- Bright ring at the FOV edge



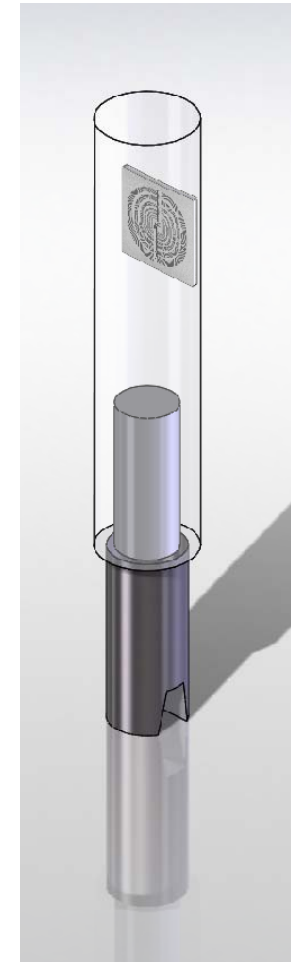
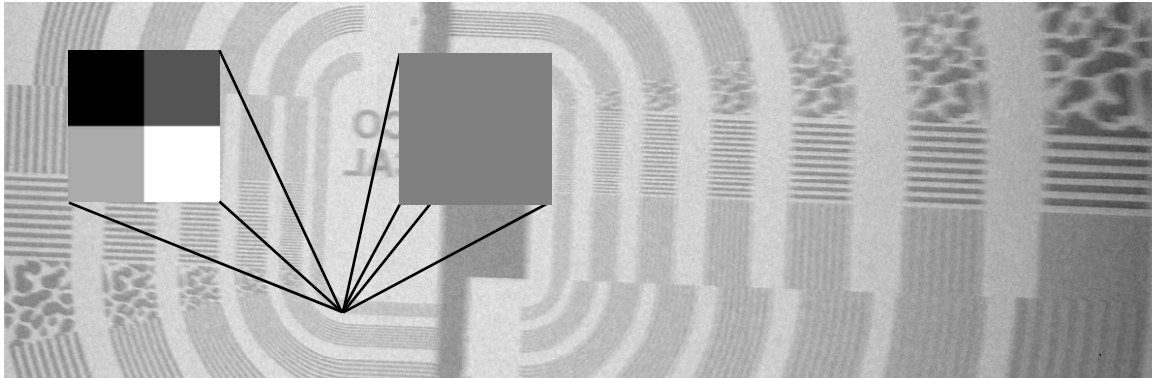
FOV/Diameter

- Smallest sample holder possible
- Scan @ the smallest "black" position
- Scan @ the largest position for fast scans of long objects (stack height)



Detector Binning

- Projection μ CT 100
- Bin factor 2.0
 - ✓ Average 4 native pixels and replace with 1 larger pixel



SW/26



Detector Binning

- Bin factor 1.0



Detector Binning

- Bin factor 4.0



Detector Binning

- Bin factor 6.0



Detector Binning

- Increases
 - ✓ Default voxel size
 - ✓ SNR
- Decreases
 - ✓ Resolution (10% MTF)
 - ✓ Raw data size
 - ✓ Image data size
 - ✓ Reconstruction time



Number of Projections

- Derived from the Nyquist-Shannon sampling theorem
 - ✓ For highest theoretical resolution

$$\frac{M}{N} = \frac{\pi}{2} \approx 1.6$$

M : Number of Projections/180°

N : Number of Detectors

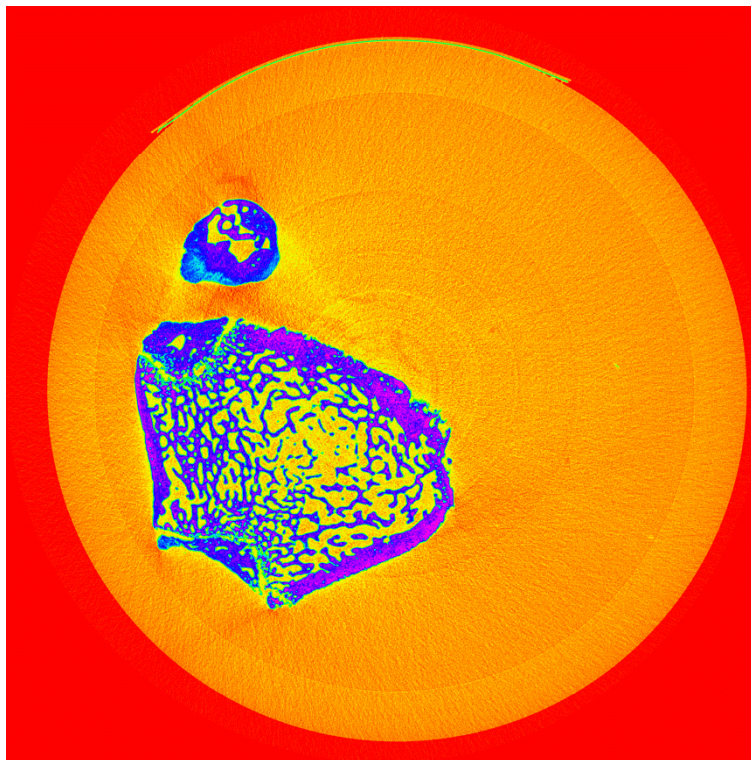
- Used in practice:

$$\frac{M}{N} = 0.5$$

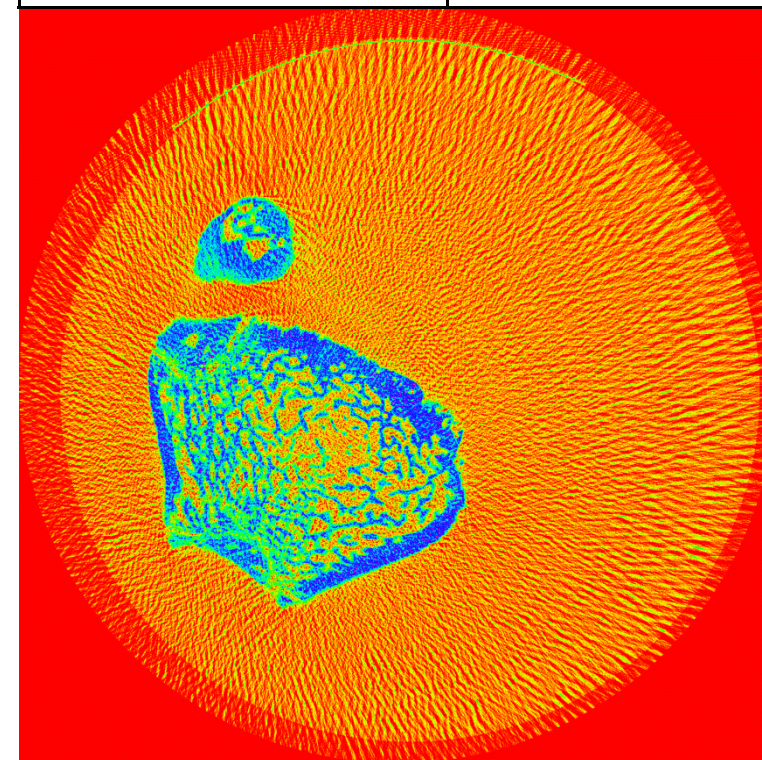


Number of Projections

Matrix	2048 x 2048
#Projections/180°	1000



Matrix	2048 x 2048
#Projections/180°	125



Resolution

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☒ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (μm): ☐ Default Size 3072x3072x306

- μ CT 100 @10 mm FOV

	Native	High	Medium	Standard
Binning	1.0	1.5	3.0	3.0
Samples	3072	2048	1024	1024
# Projections/180°	1500	1000	500	250
Default Voxel Size	3.3 μm	5.0 μm	10.0 μm	10.0 μm

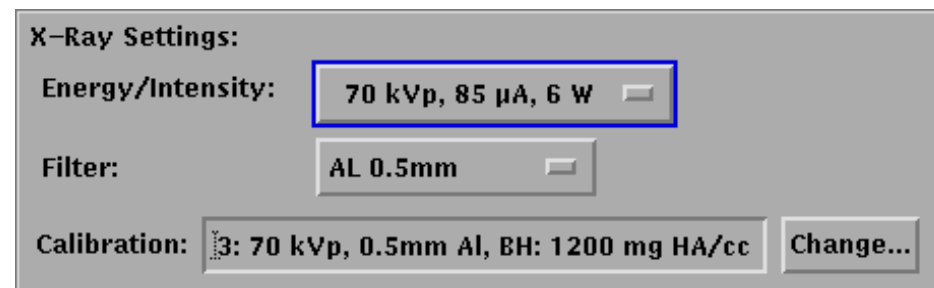


Resolution

- From medium to high resolution
 - ✓ Increase
 - Number of projections
 - Scan time
 - Dose
 - Resolution
 - Raw data size
 - Image data size
 - Reconstruction time
 - ✓ Decrease
 - SNR
- Do you really need high resolution scans?



Power Setting



X-Ray Settings:

Energy/Intensity: 70 kVp, 85 μ A, 6 W ☐

Filter: AL 0.5mm ☐

Calibration: 3: 70 kVp, 0.5mm Al, BH: 1200 mg HA/cc

- X-ray focal spot size is limited by the power setting
 - ✓ Too much heat on a small spot melts the target
 - ✓ Higher power results in a larger focal spot



Power Setting

- Focal spot creates blurred projections depending on
 - ✓ Focal spot size
 - ✓ Geometrical magnification

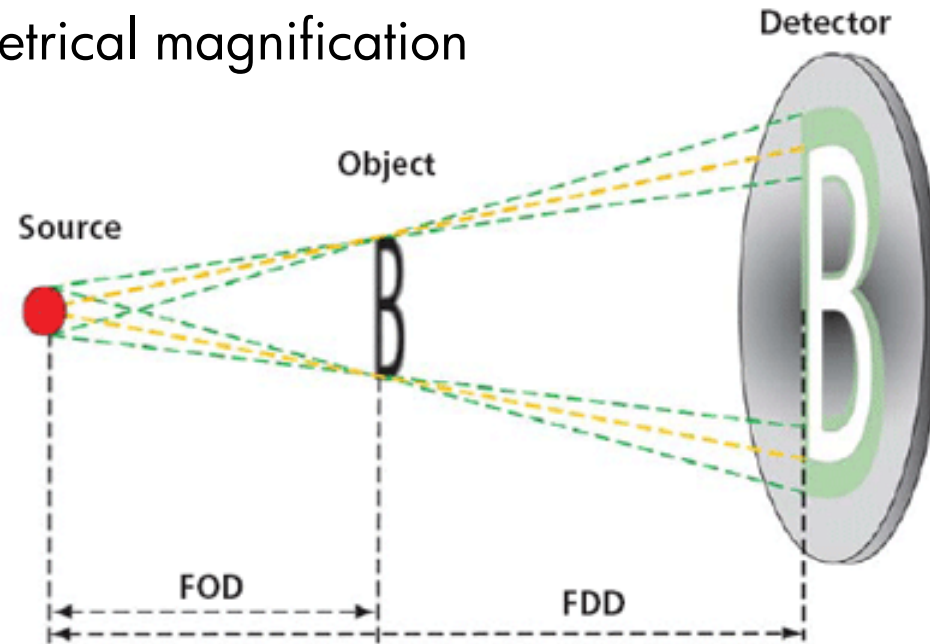


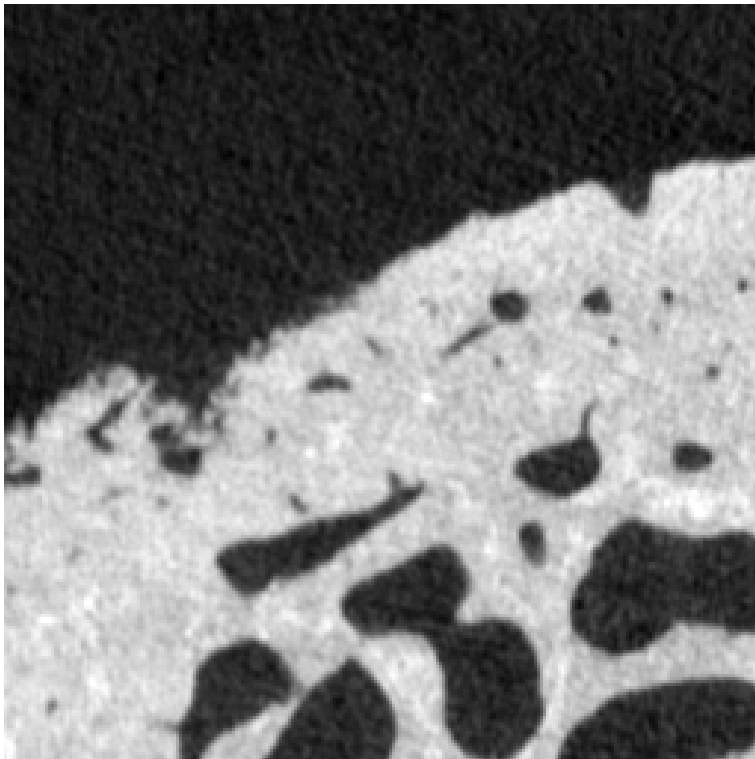
Figure 1. Operating Principle of Microfocus X-Ray Inspection

<http://www.evaluationengineering.com>

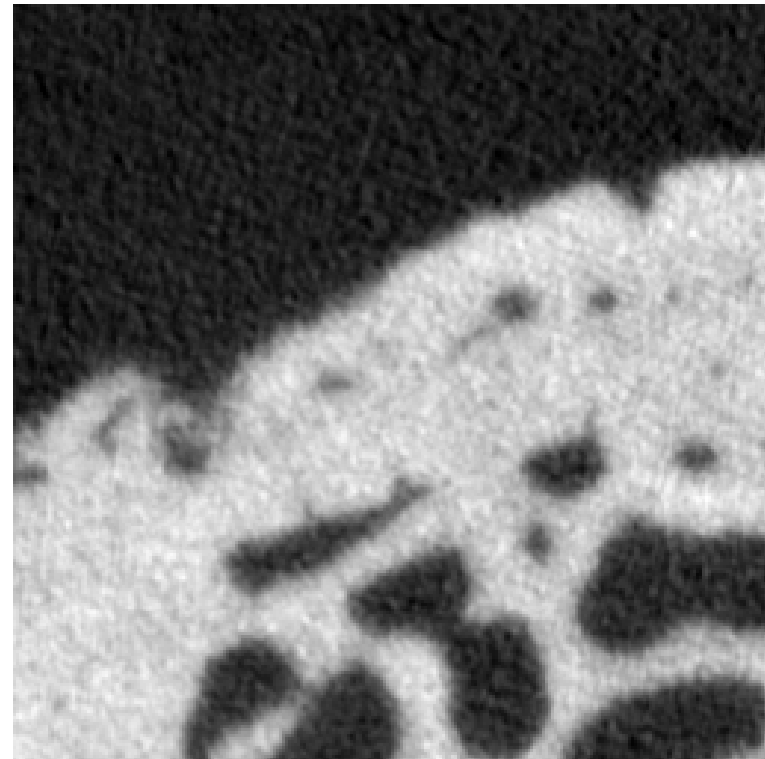


Power Setting - Resolution

- Rat femur



6 W @ 15 mm FOW



14 W @ 15 mm FOW



Focal Spot Size – 10% MTF

- μ CT 100, 10 mm FOV, native resolution

Power [W]	10% MTF [μ m]	Voxel Size [μ m]
4	4.3	3.3
6	5.5	3.3
8	7.0	3.3
14	9.9	3.3
18	12.0	3.3



Focal Spot Size – 10% MTF

- μ CT 100, 10 mm FOV, native resolution

Power [W]	10% MTF [μ m]	Voxel Size [μ m]
4	4.3	3.3
6	5.5	3.3
8	7.0	3.3
14	9.9	3.3
18	12.0	3.3



Focal Spot Size – 10% MTF

- μ CT 100, 105 mm FOV, native resolution

Power [W]	10% MTF [μm]	Voxel Size [μm]
4	57	34
6	57	34
8	57	34
14	57	34
18	57	34



Focal Spot Size – 10% MTF

- μ CT 100, 105 mm FOV, native resolution

Power [W]	10% MTF [μ m]	Voxel Size [μ m]
4	57	34
6	57	34
8	57	34
14	57	34
18	57	34



Power Setting

- For μ CT 35, μ CT 50, μ CT 100
 - ✓ Choose power setting according to
 - Resolution setting
 - FOV (object position)
 - ✓ Rule of thumb
 - Choose power in Watt $\leq$ default voxel size in μ m
 - ✓ Some power/resolution combinations are questionable
- For μ CT 80, μ CT 40, vivaCT, XtremeCT
 - ✓ Choose highest power setting



Advanced Mode

Definition of Controlfiles...

Control filename: SW Bone User Meeting 2013

☒ Basic ☒ **Advanced**

Holder Type: 1150024, p 18mm x 1184mm

Mode:

Evaluation: Default Evaluation

X-Ray Settings:

Energy/Intensity: 70 kVp, 57 μ A, 4 W

Filter: AL 0.5mm

Calibration: 3: 70 kVp, 0.5mm AL, 6H: 1200 mg HA/cc

Scout-View:

☒ enabled ☐ disabled

Start Position (mm): 50.000

End Position (mm): 51.000

Angle (°): 0

CT-scan:

Resolution: ☒ Standard ☐ Medium ☐ High ☒ Native ☐ Custom

FOV/Diameter [mm]: ☒ 10.2 ☒ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxel size (μ m): 3.3 ☐ Default Size 3072x3072x620

Number of Slices: 620 2.05 mm (2x310/310)

Rel. Position of First Slice to Ref. Line (mm): .000

Integration Time (ms): 500

Average Data: 1

Number of Det. Lines: 390

FOV/Scandiameter: 10.237

SW Binning: 1.000

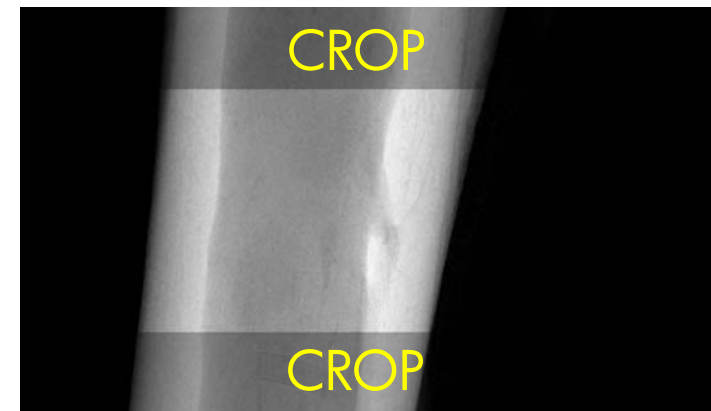
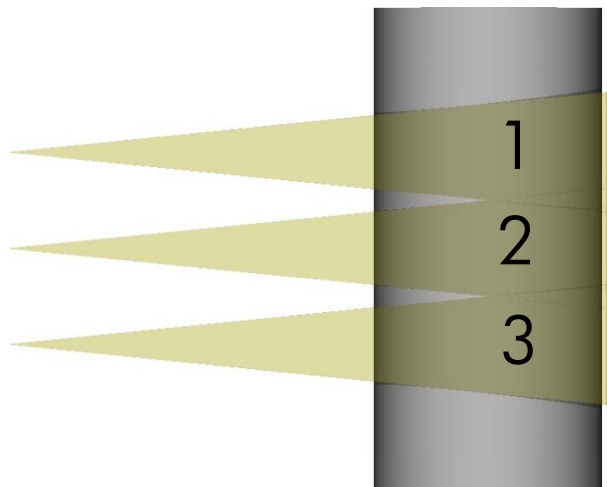
HW-Binning: ☒ 1x1

Samples: 51972 Prei/180°: 3508

Tot. No. of Slices: 620 Meas. Time: 61.9 min (178 mAs)

Scout View Detector Lines

- Scout view scheme
 - ✓ Cone beam projections from 1 angle
 - ✓ Introduces geometrical distortions



Scout-View:

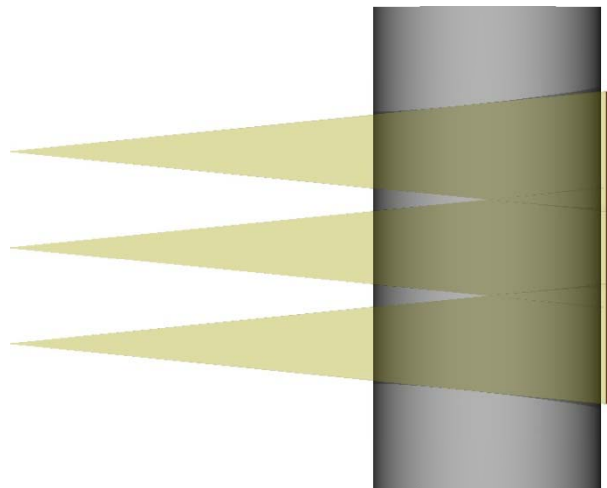
☒ enabled ☐ disabled

Number of Det-Lines: 195

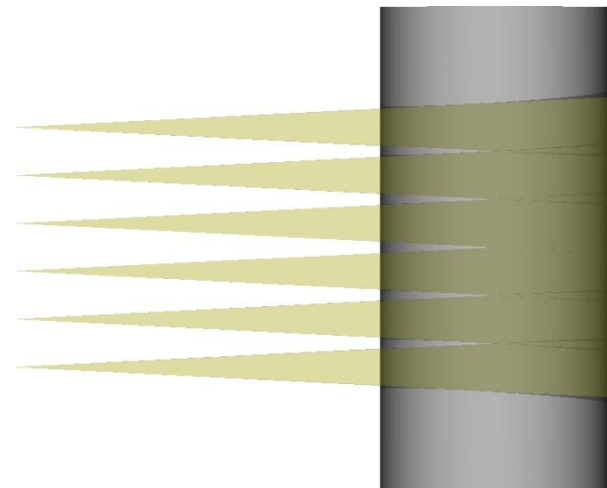


Scout View Detector Lines

- Reduce number of detector lines (crop sensor) to reduce geometrical distortions



390 lines



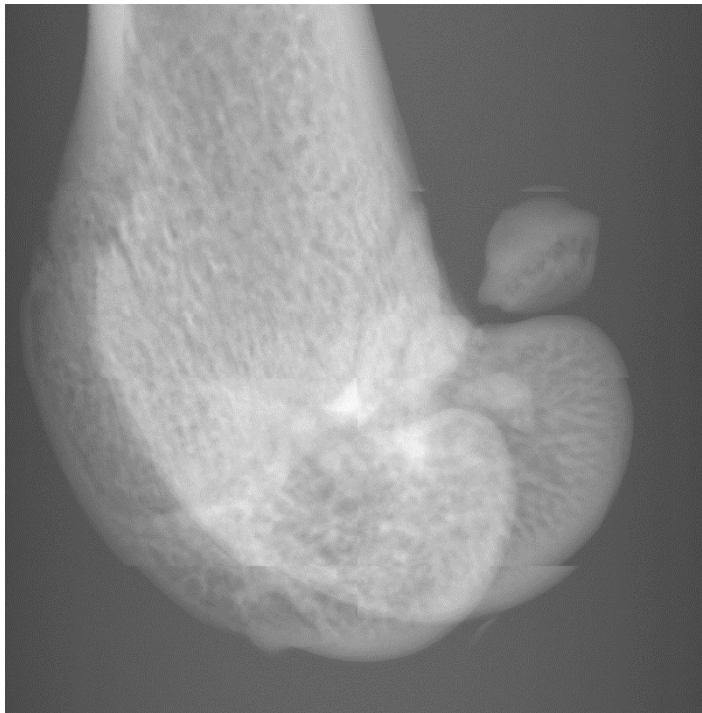
195 lines



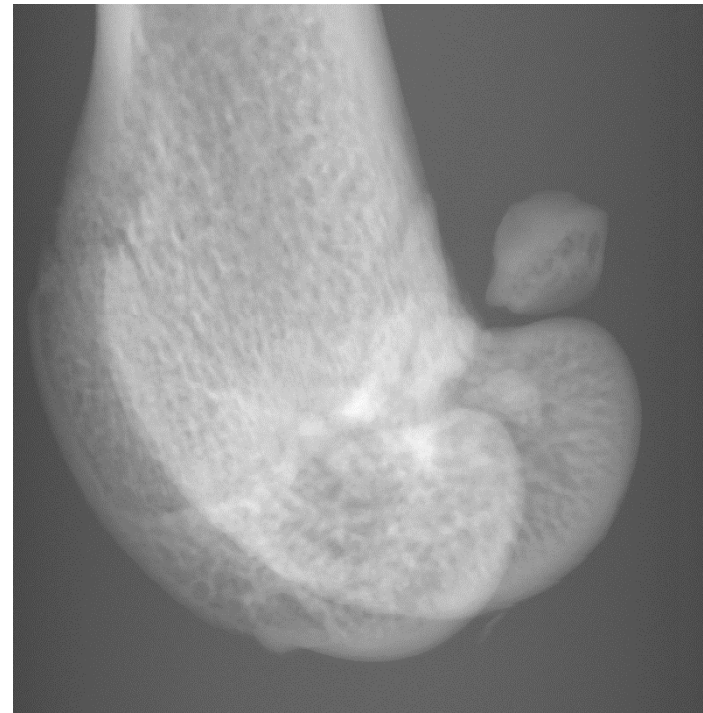
Scout View Detector Lines

- Limit number of detector lines for nice scout views
 - ✓ Dose increases

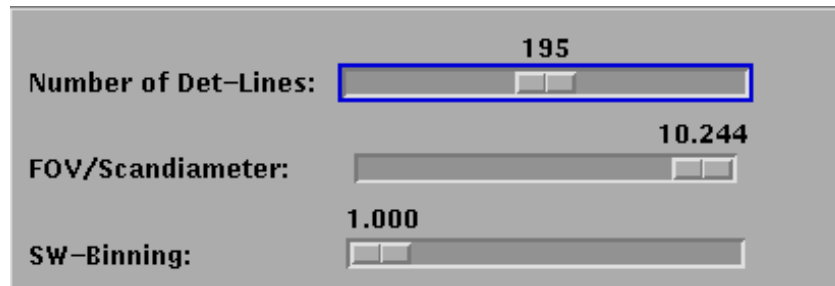
390 lines



50 lines



Scan Detector Lines



Number of Det-Lines: 195

FOV/Scandiameter: 10.244

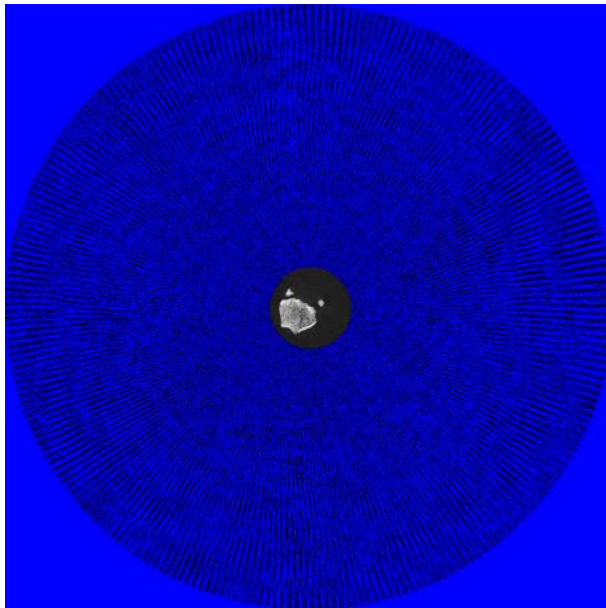
SW-Binning: 1.000

- Fewer detector lines
 - ✓ Reduce cone-beam effects
 - ✓ Reduce artifacts between stacks
 - ✓ Sharp edges in z-direction (objects boundary)
 - ✓ Increase scan time
 - ✓ Increase dose



FOV/Scandiameter

- Small object in large FOV



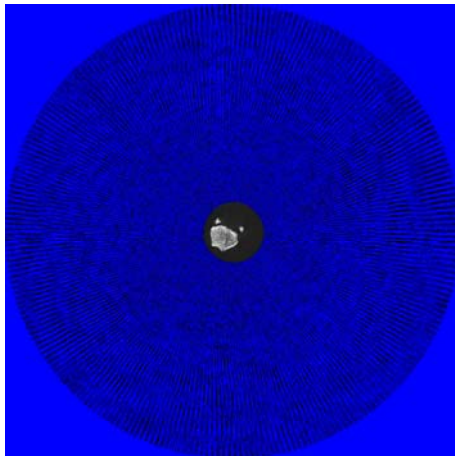
Number of Det-Lines:	390
FOV/Scandiameter:	15.049

15 mm Ø in 105 mm FOV
Cropped to 15 mm

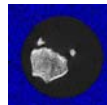


FOV/Scandiameter

- Small object in large FOV



15 mm Ø in 105 mm FOV



15 mm Ø in 105 mm FOV
Cropped to 15 mm

Number of Det-Lines:

FOV/Scandiameter:

	Uncropped	Cropped
Stack Height [mm]	10.5	13.5
Projection Size [MB]	1.2	0.2
Image Slice Size [MB]	19	0.4

SW/49



FOV/Scan Diameter

- Crop sensor in radial direction if the sample does not fill the FOV
 - ✓ Increase
 - Stack height
 - ✓ Decreases
 - Raw data size
 - Image data size
 - Reconstruction time



Arbitrary Software Binning

Number of Det-Lines:

FOV/Scandiameter:

SW-Binning:

HW-Binning:

Samples: Proj/180°:

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☐ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (µm): ☐ Default Size 3072x3072x310

Number of Slices: 1.02 mm (1x310/310)

Arbitrary Software Binning

Number of Det-Lines:

FOV/Scandiameter:

SW-Binning:

HW-Binning:

Samples: Proj/180°:

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☐ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (µm): ☐ Default Size 900x900x310

Number of Slices: 3.50 mm (4x78/90)

Hardware Binning

- Hardware binning for μ CT 50, XtremeCT II, vivaCT 80
 - ✓ Performed by the detector
 - ✓ Only integer bin factors
 - ✓ Faster detector readout
 - Faster scan

The screenshot displays a software interface for configuring hardware binning. The settings are as follows:

Parameter	Value
Number of Det-Lines:	390
FOV/Scandiameter:	10.241
SW-Binning:	1.500
HW-Binning:	1x1 (selected)
Samples:	2048
Proj/180°:	1000



Number of projections

- Even number of projections

CT-Scan:			
Resolution:	☒ Standard ☐ Medium ☐ High ☐ Native ☐ Custom		
FOV/Diameter [mm]:	☒ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1		
Voxelsize (µm):	☒ 34.2 ☐ Default Size 440x440x309		
Number of Slices:	309 10.57 mm (1x309/393)		
Rel. Position of First Slice to Ref. Line (mm):	.000		
Integration Time (ms):	500		
Average Data:	1		
		Number of Det-Lines: 390	
		FOV/Scandiameter: 15.049	
		SW-Binning: 1.000	
		HW-Binning: ☒ 1x1	
		Samples: 3072 Proj/180°: 220	



Non Default Voxel Size

- Finer sampling in the reconstruction algorithm

CT-Scan:

Resolution: ☐ Standard ☐ Medium ☐ High ☐ Native ☐ Custom

FOV/Diameter [mm]: ☐ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

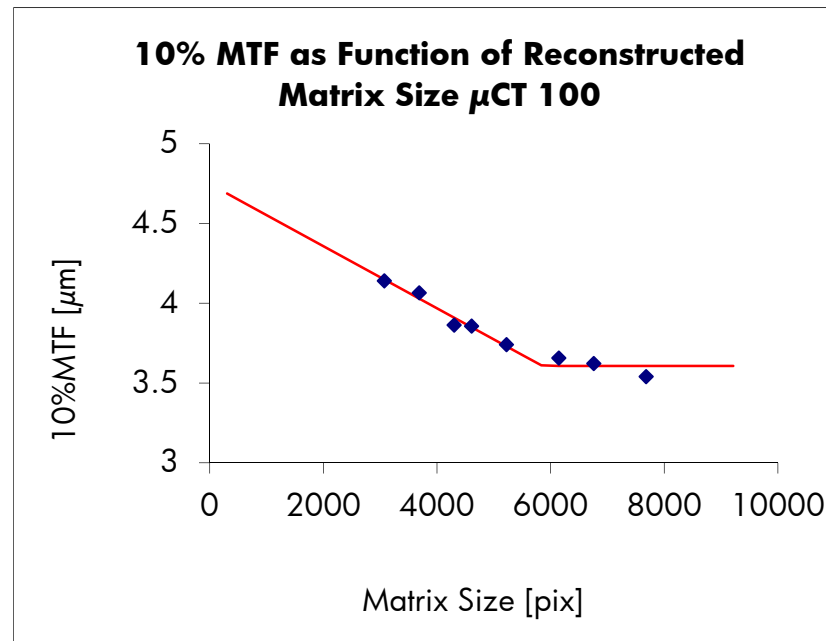
Voxelsize (μm): ☐ Default Size 8192x8192x620

- Matrix size up to 8192x8192
- Voxel size down to 1.2 μm for μCT 100, FOV 10 mm



Non Default Voxel Size

- μ CT 100, 10 mm FOV, 4 W, 10 % MTF

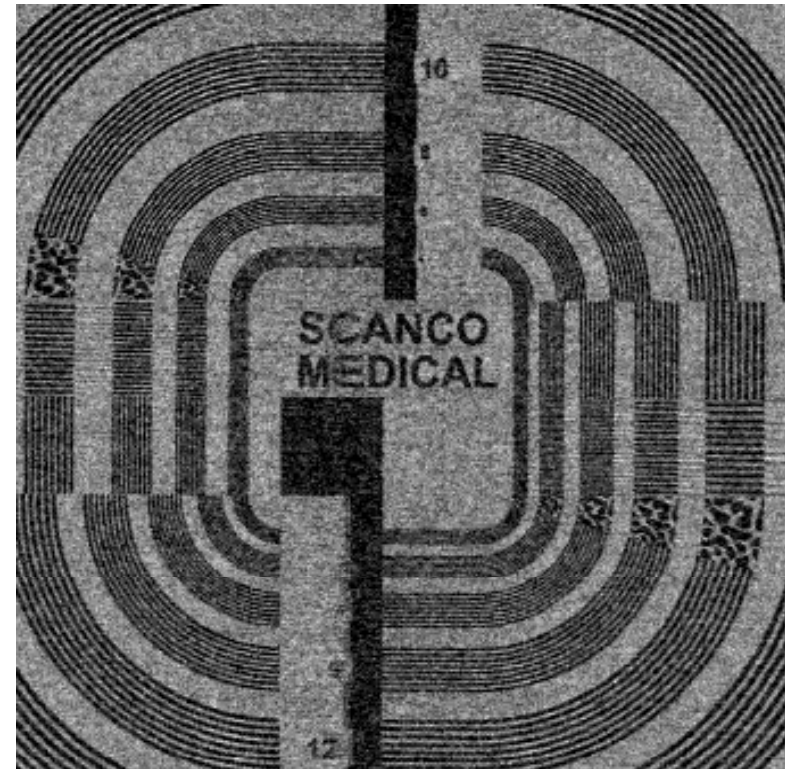
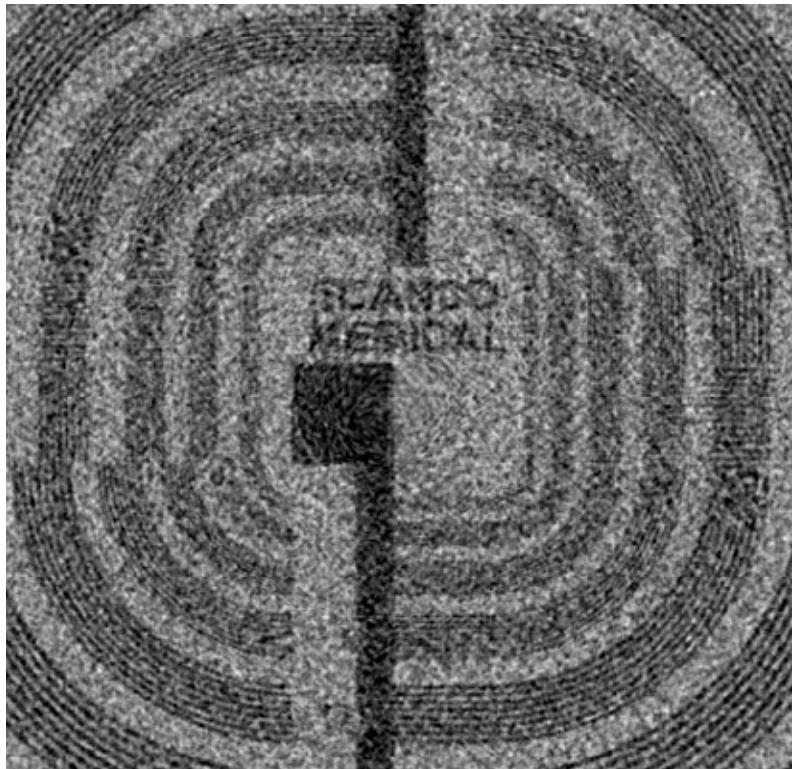


- Resolution gain only to a factor 2.0
 - ✓ E.g. 3072x3072 to 6144x6144



Resolution and Integration Time

- Identical scan parameters, except integration time



Resolution and Integration Time

- Technical definition (10% MTF)
 - ✓ Resolution is a system response
 - ✓ Resolution definition is integration time independent
 - Integrate as long as possible
 - ✓ Resolution is masked by noise
 - Averaging N noisy images would reveal fine structures
 - ✓ Images have the same resolution
- Practical definition (separation of line pairs)
 - ✓ Right image has higher resolution



CT-Scan:

Resolution: ☒ Standard ☐ Medium ☐ High ☐ Custom

FOV/Diameter [mm]: ☒ 10.2 ☐ 15.2 ☐ 20.5 ☐ 35.2 ☐ 50.4 ☐ 75.4 ☐ 90.1 ☐ 105.1

Voxelsize (µm): ☐ Default Size 8192x8192x306

Number of Slices: 0.37 mm (1x306/854)

Rel. Position of First Slice to Ref. Line (mm):

Integration Time (ms):

Average Data:

Number of Det-Lines:

FOV/Scandiameter:

SW-Binning:

HW-Binning: ☒ 1x1

Samples: Proj/180°:

Thank You for Your Attention

