

Porosity Characterisation in Carbon Composites by X-Ray Computed Tomography and Image Analysis and Validation by Materialografic Targeted Microsection



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"Innovative
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Advantages of Carbon Fibre Reinforced Plastics (CFRP)

- Very high mechanical strength
- 50 % weight reduction compared to steel, 30 % compared to Al
- High modulus of elasticity
- Resistance to corrosion
- Very good fatigue strength

Present disadvantages

- High production costs
- Long production time



Development efforts in industry

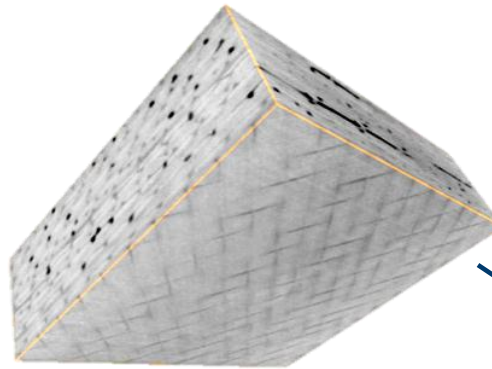
- Reduce production costs
- Reduce production time
- Realize mass production
 - Developing the Resin Transfer Moulding (RTM) technology
 - Porosity formation is immanent in the manufacturing process
- Rule of thumb: **1% porosity decrease mechanical strength 10%**

Reasons for research

- Porosity decreases mechanical strength
- Distribution, size and shape of pores influences strength
- Necessity is the evaluation of these pore parameters

Purpose of the research

Mikro-CT and 3-D-Image-Analysis is a tool for



Development of Non-Destructive
Testing (NDT) –Methods

- Ultrasound
- Thermography

Strength tests

X-ray computer tomography

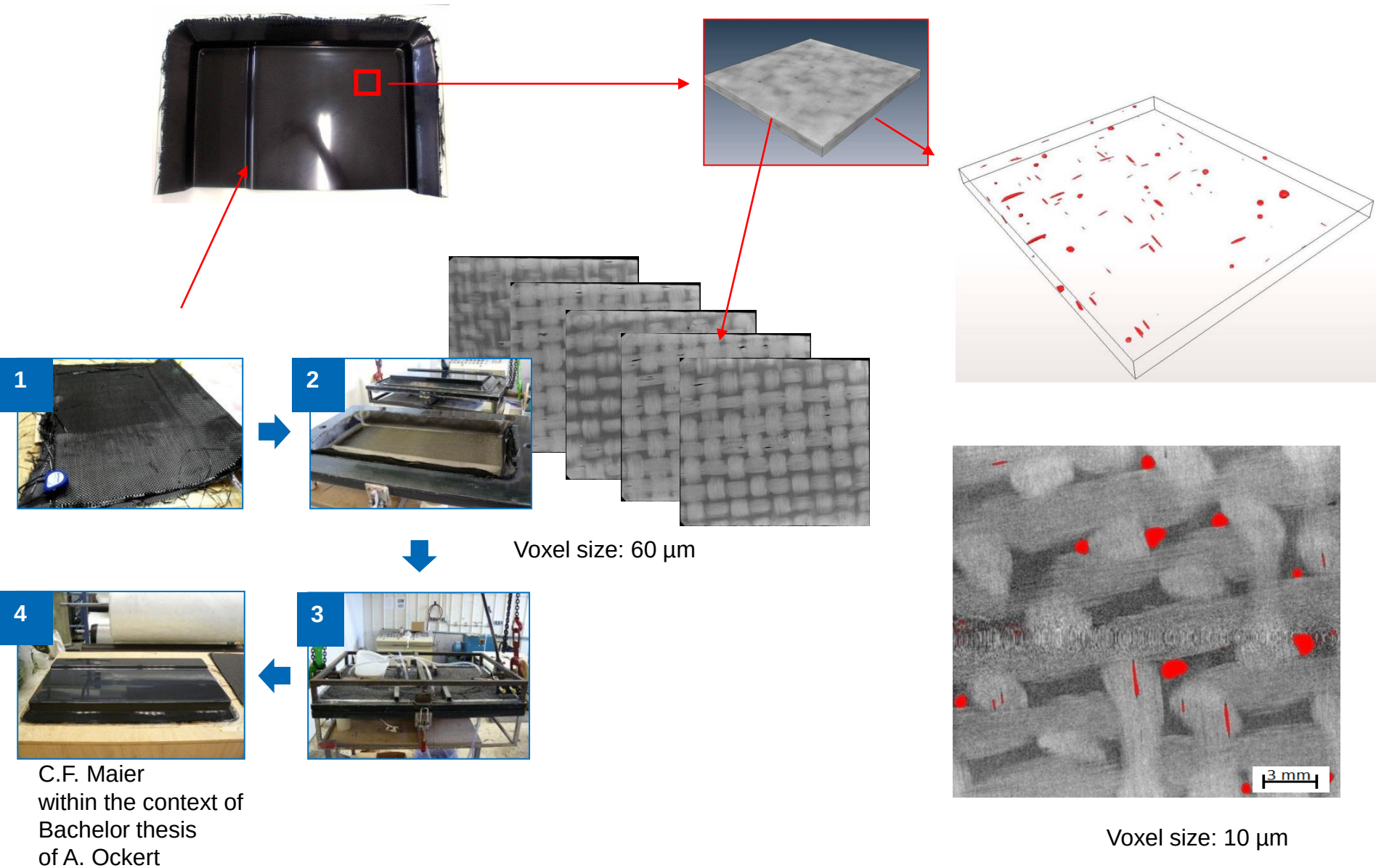


Phoenix v|tome|x s

Parameter	Micro focus	Nano focus
Resolution	20 μm	10 μm
Current	240 kV	180 kV

- **Digital detector:**
2000 x 1500 Pixel, Pixel size ca. 124 μm
- **Detail perceptibility:**
< 1 μm (Nano focus tube)
- **Software used for analysis:**
Volume Graphics VGStudio MAX 2.0

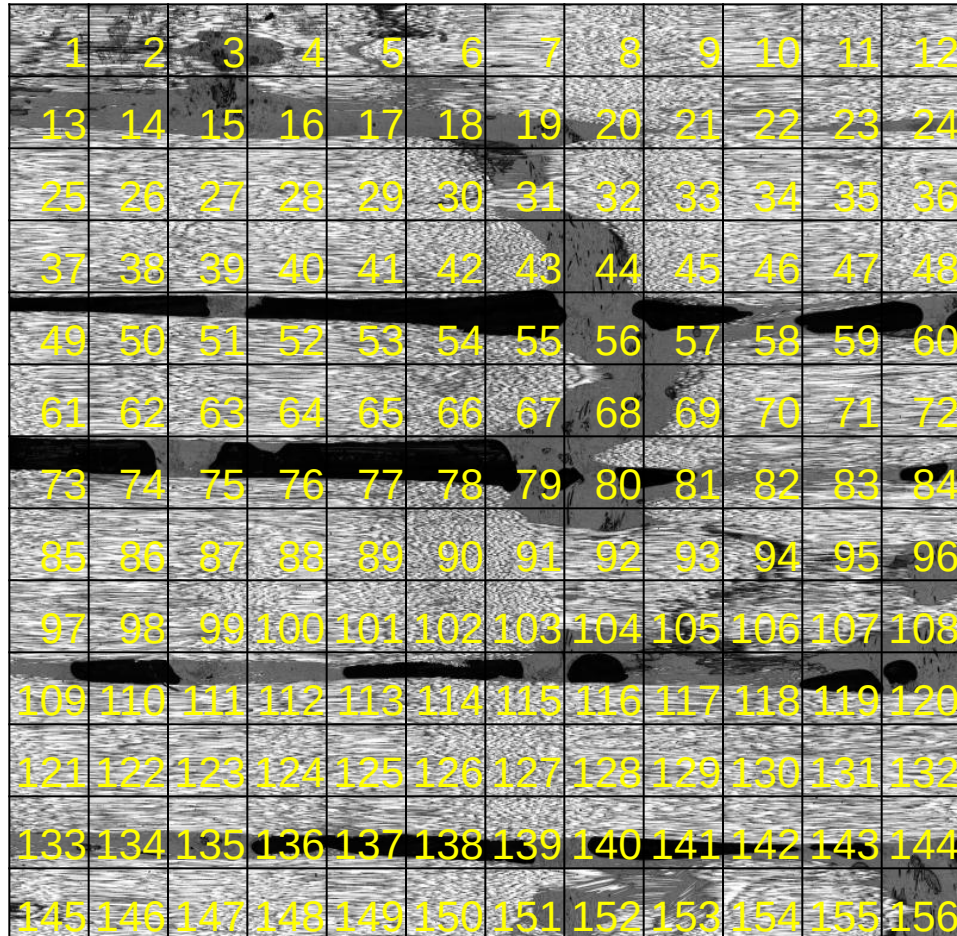
Samples Preparation and Computed Tomography Measurements



- **Problem 1- Verification and Validation of volume porosity till now only by chemical analysis**
 - **No statement possible regarding the size distribution, orientation and shape of pores**
- **Problem 2 - Calibration**
 - **define threshold value**

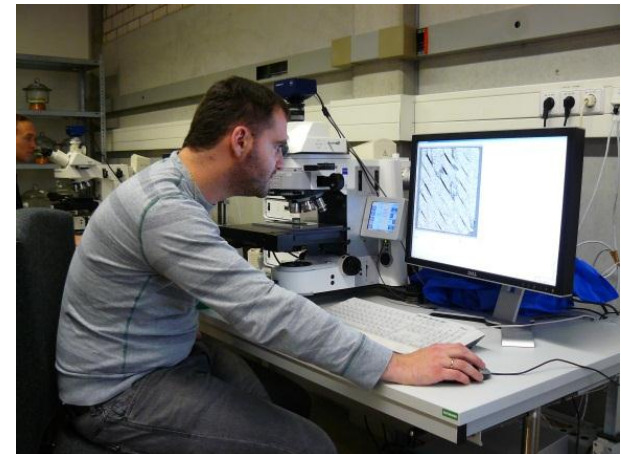
Targeted Microsection and Light Microscopy for Verification and Calibration

Light microscope – image acquisition



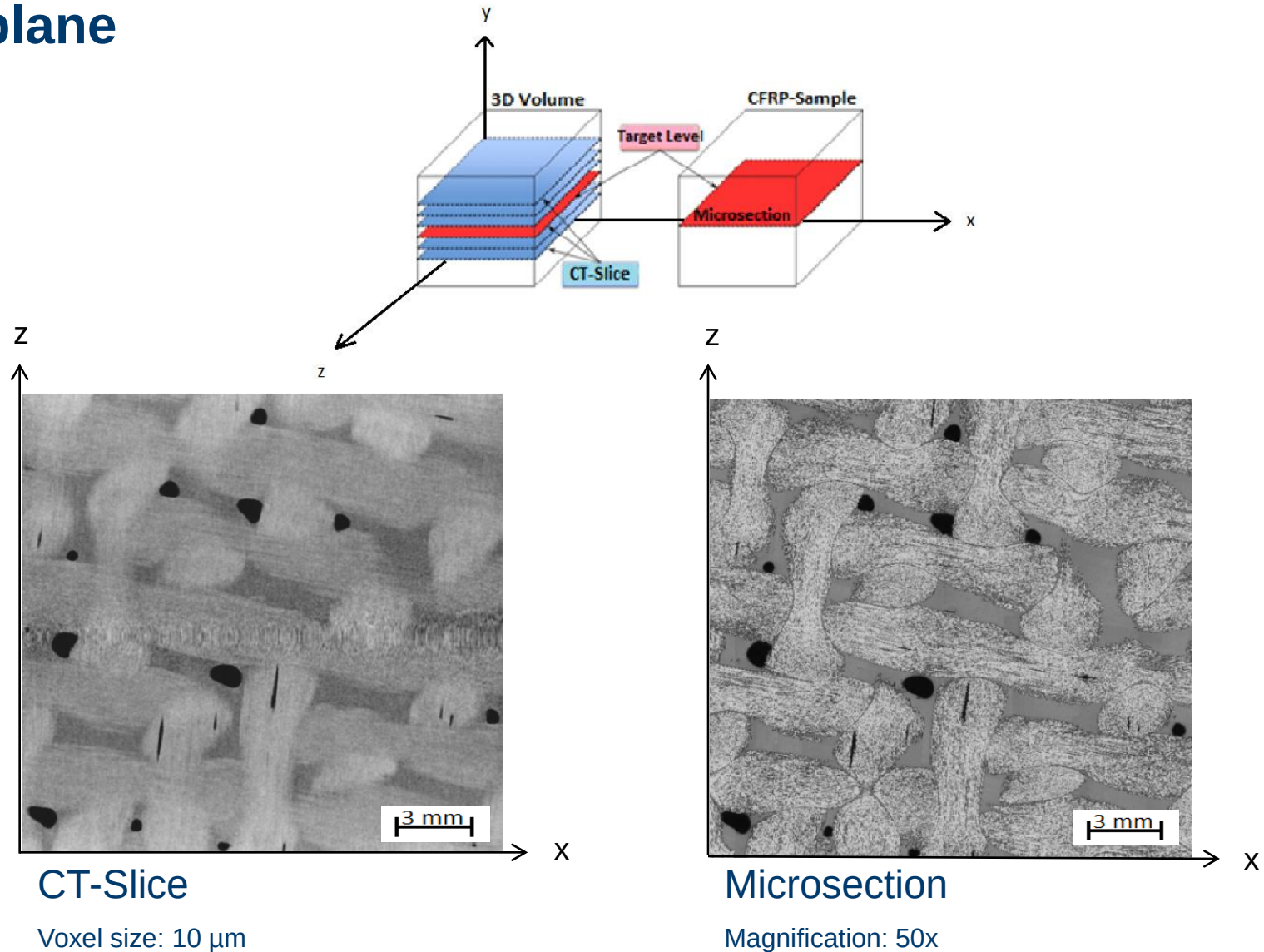
Mosaik-Image

- Take single images
 - Overlap of images of 10 %
 - Stitch images together
- Creating one image with 50x magnification

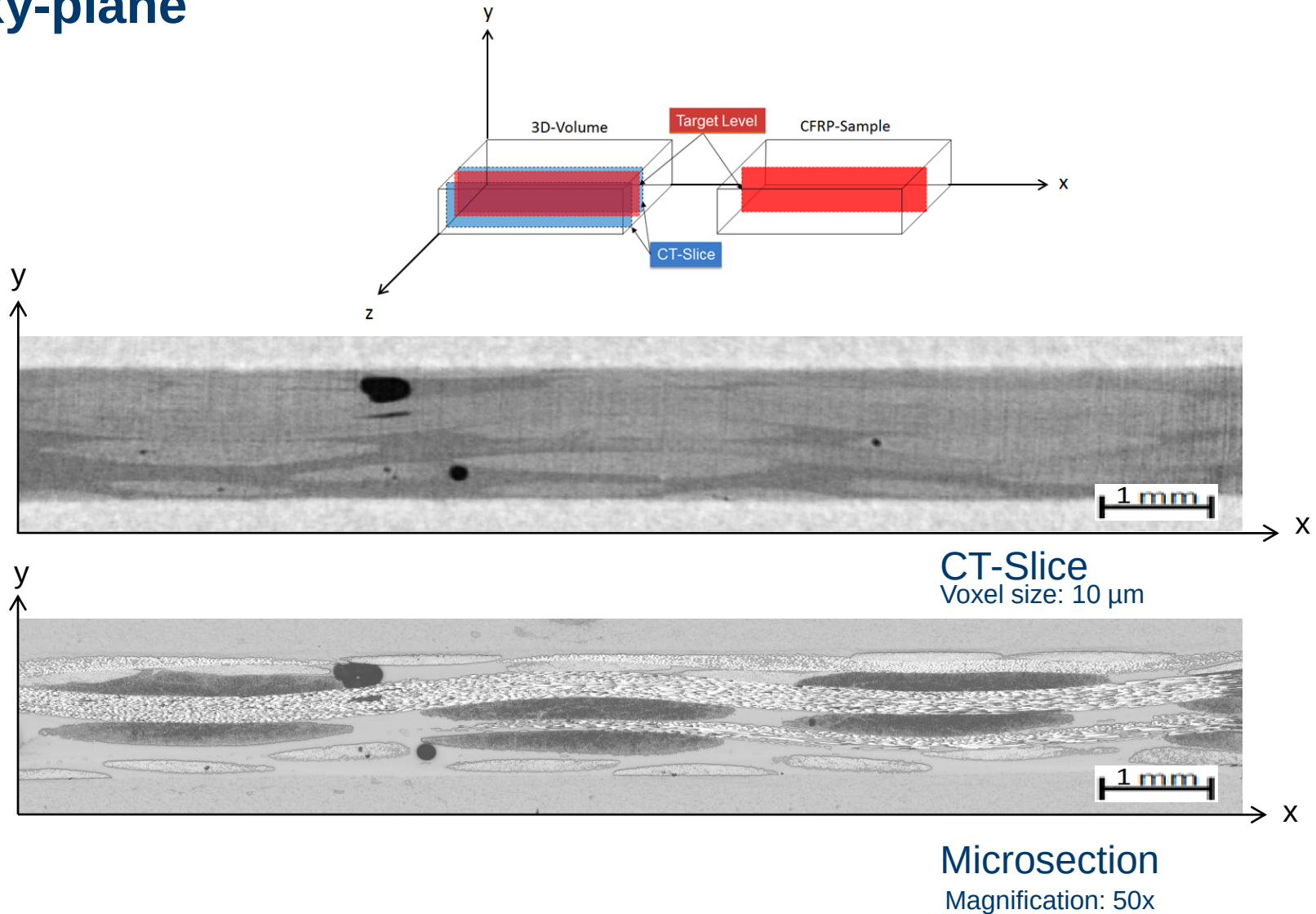


Comparison of CT-Slice and Microsection

Comparison of CT-Slice and Microsection xz-plane

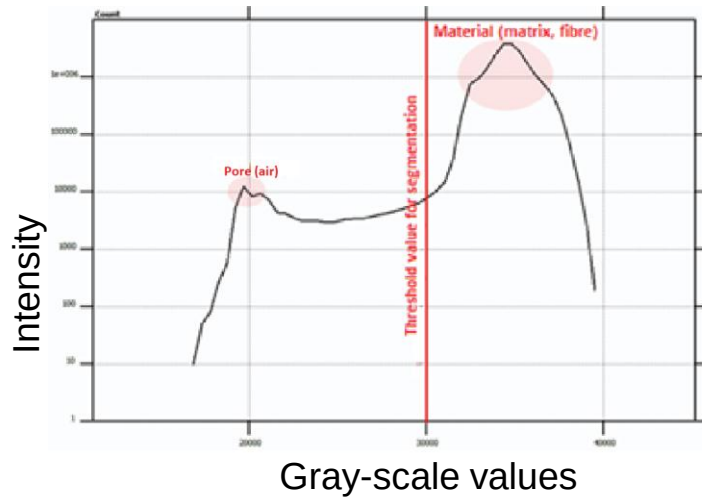


Comparison of CT-Slice and Microsection xy-plane

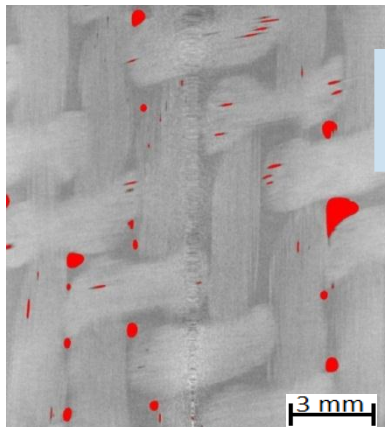


Segmentation with interactive global threshold value method

Histogram



- graphic representation of grey-scale values in one image

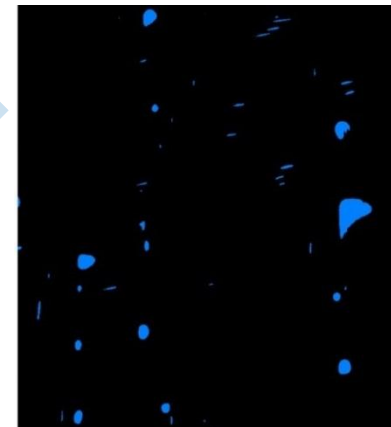


Segmented image

Creating an output image with segments 0 and 1

$$T_{global}(g) = \begin{cases} 0 & \text{if } g < t \\ 1 & \text{if } g \geq t \end{cases}$$

g : grey value
 t : threshold value

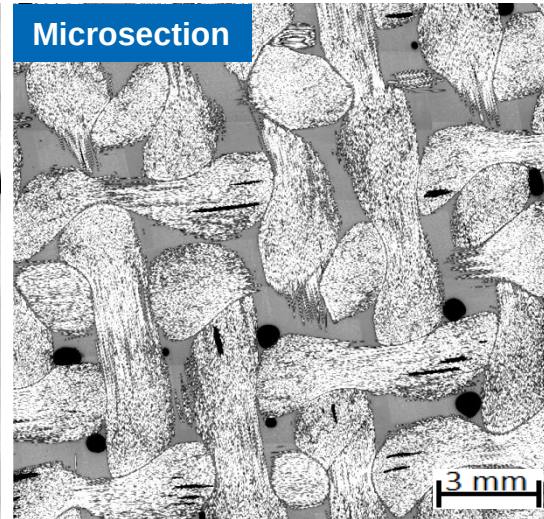
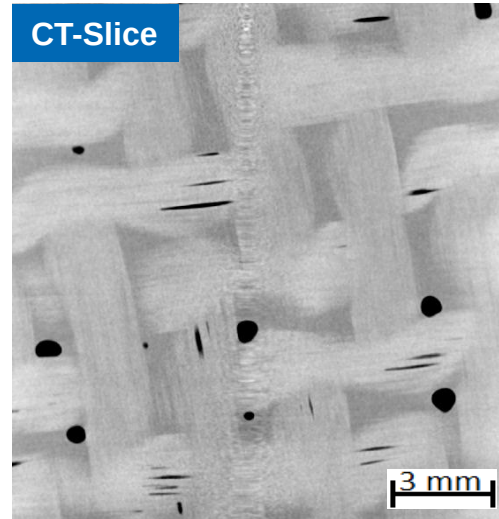


Binary image

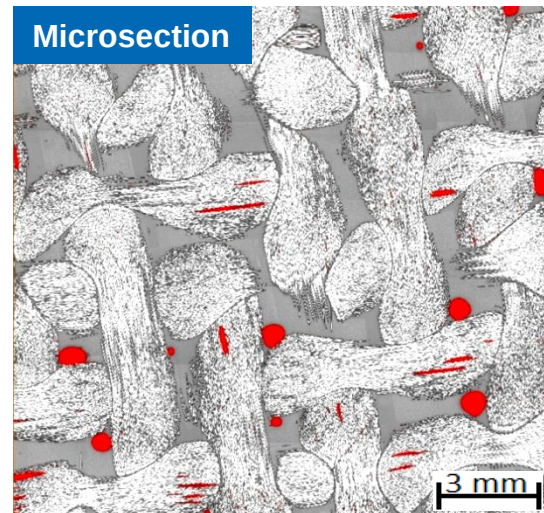
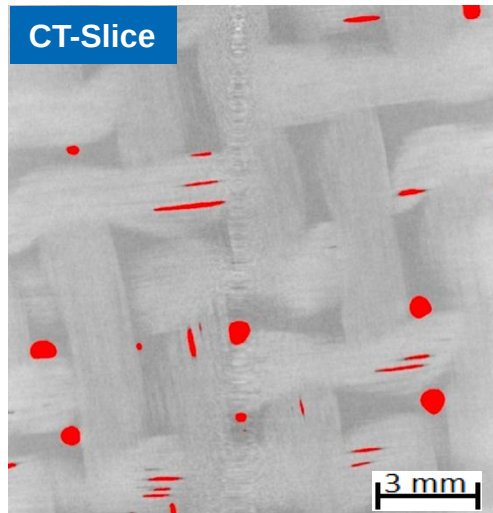
Analysis

Calibration by Comparision of segmented CT-Slices with Microsection (2D)

Longitudinal microsection



Not segmented



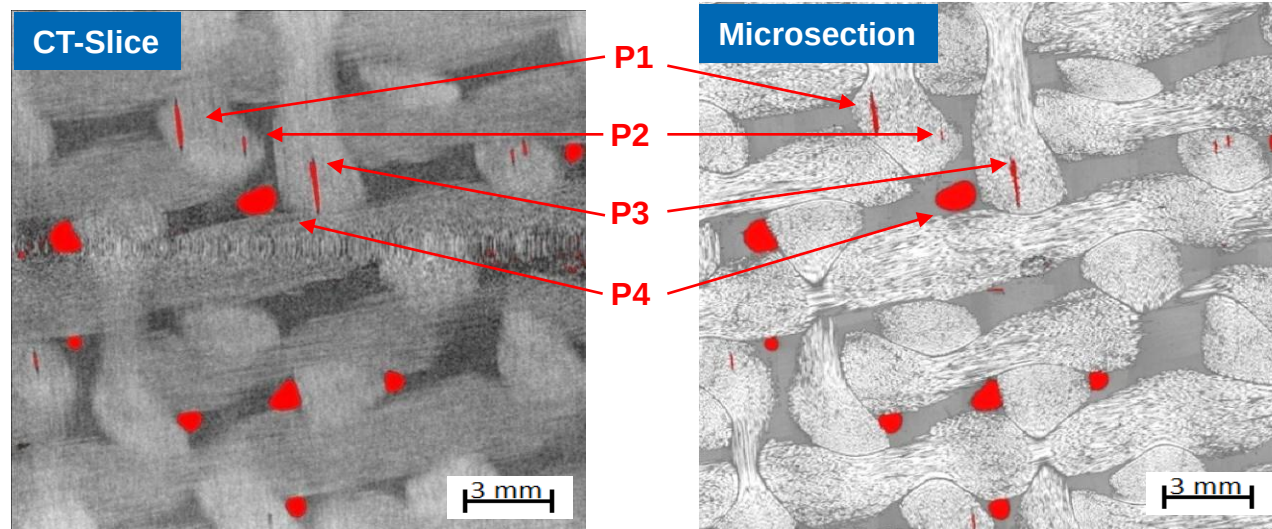
Segmented
CT-Slice and
Microsection

Voxel size: 10 μm

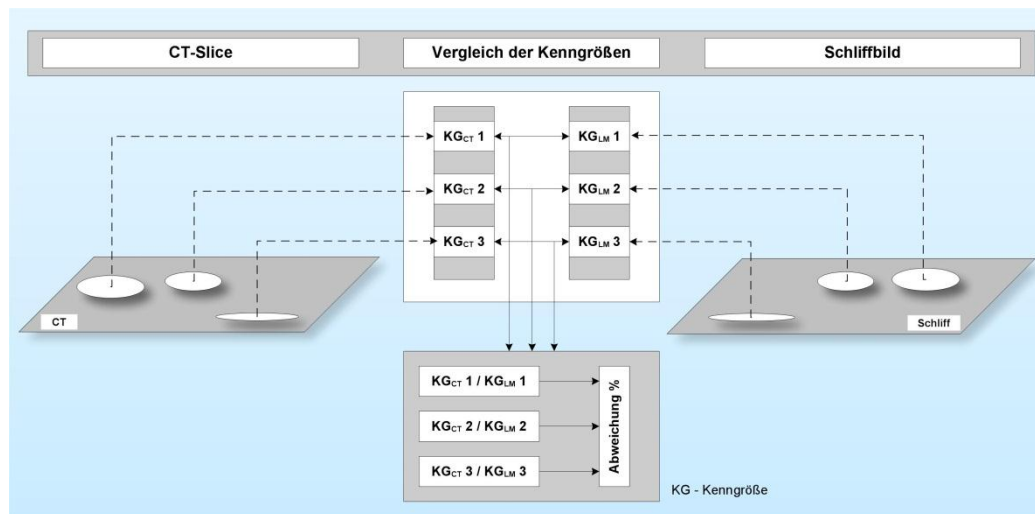
Transverse microsection

- Wird Montag hinzugefügt

Evaluation - Comparison of pores parameters of CT-Slices and Microsection

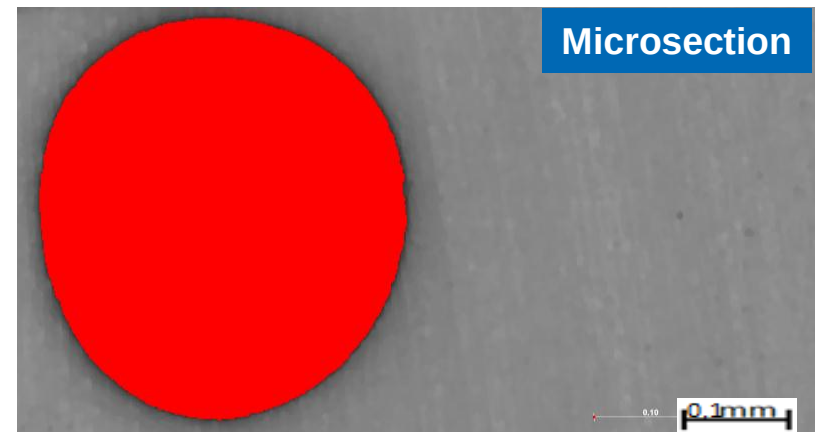
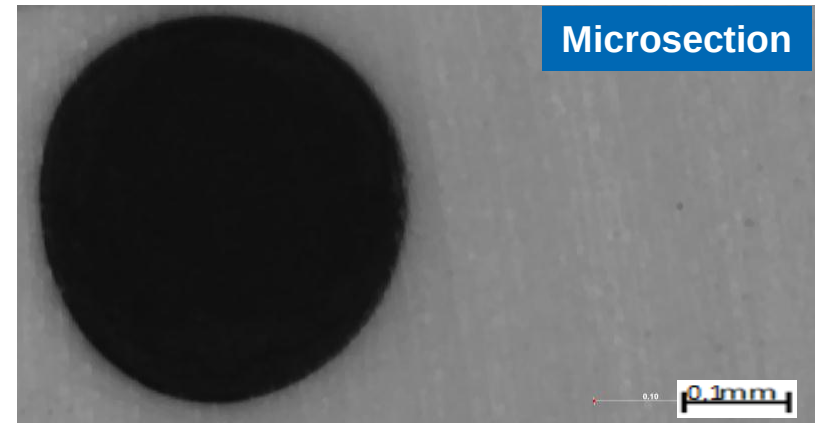
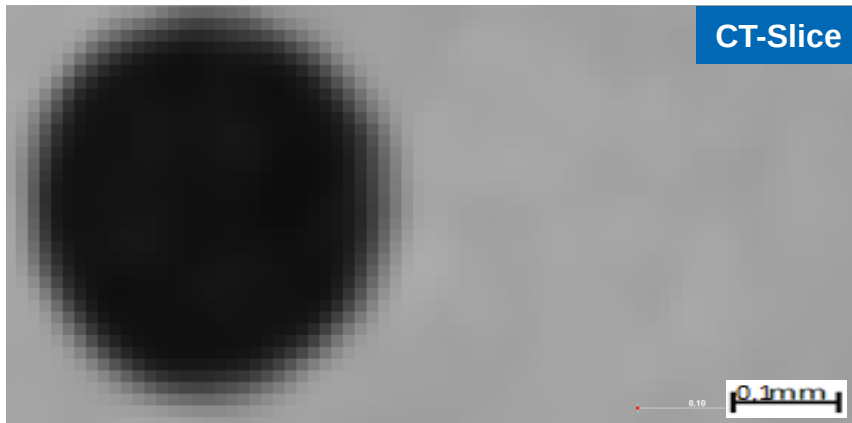


Segmentation of Pores and creating pairs

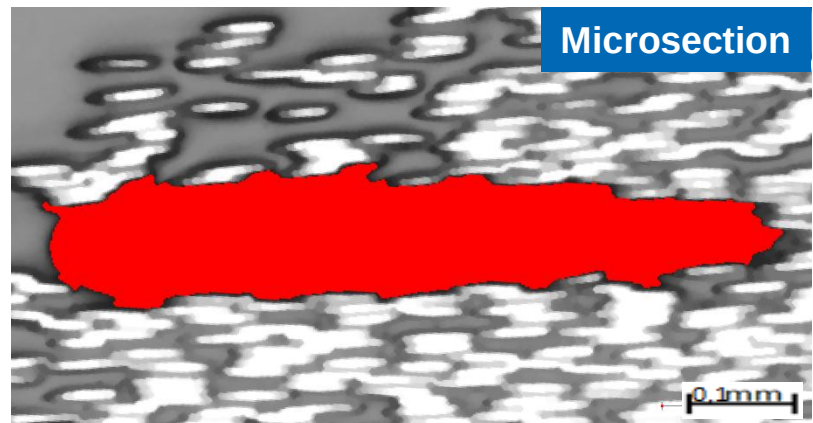
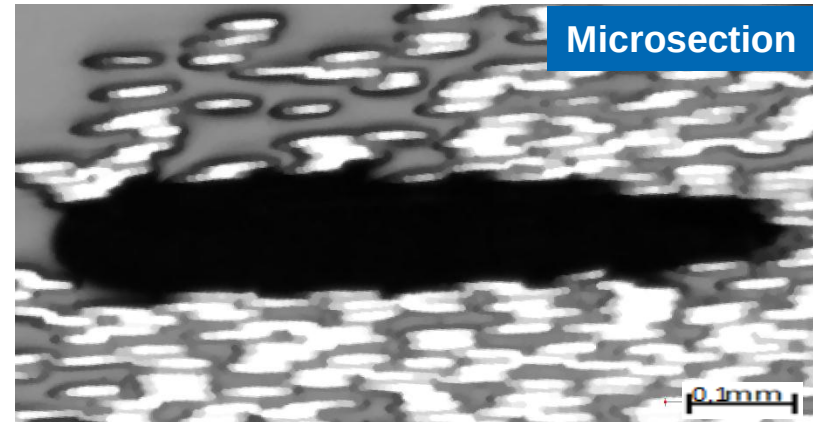
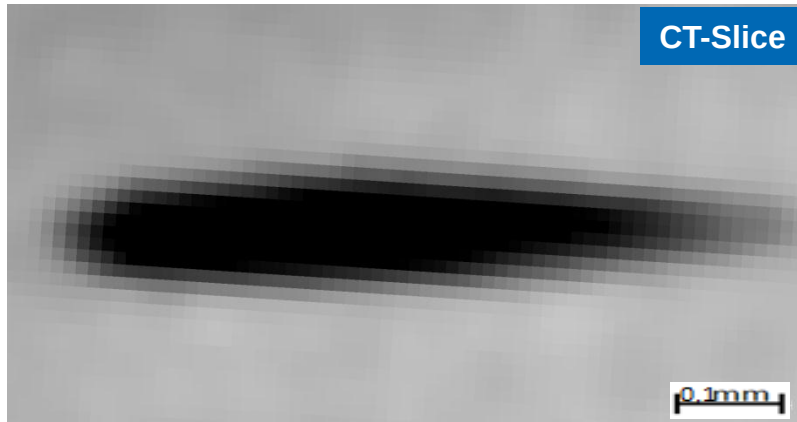


Comparison of parameters and calculating deviation

Magnification of a rounded pore

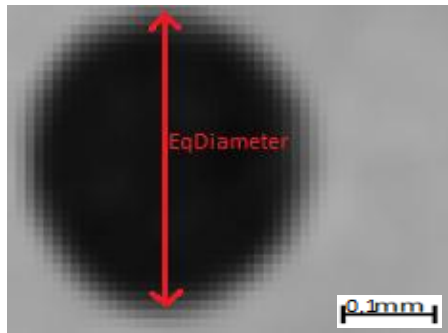


Magnification of a elongated pore

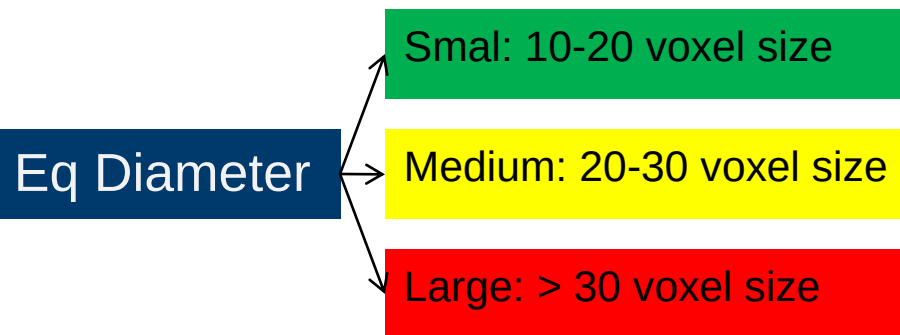


Classification

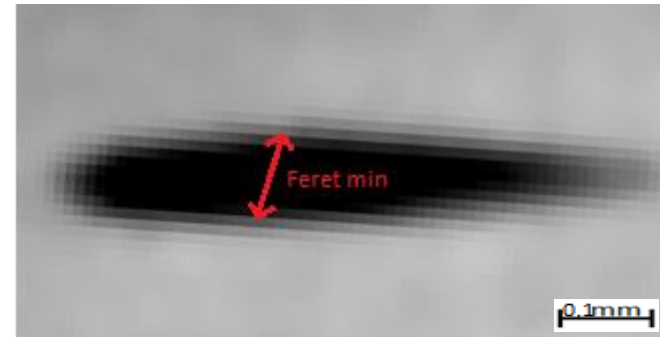
Rounded shape



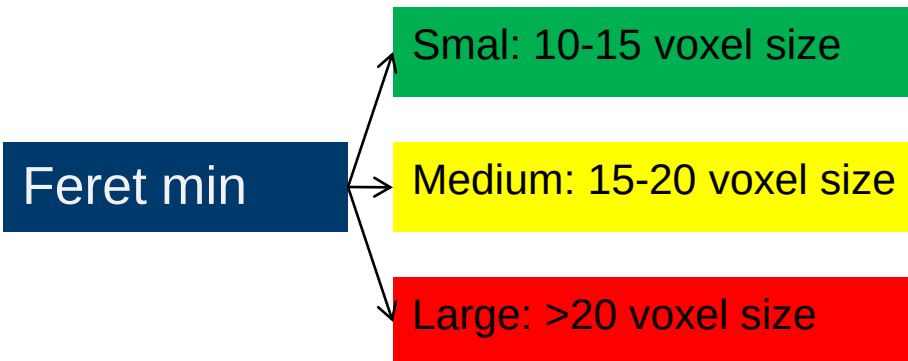
- based on the equivalent diameter



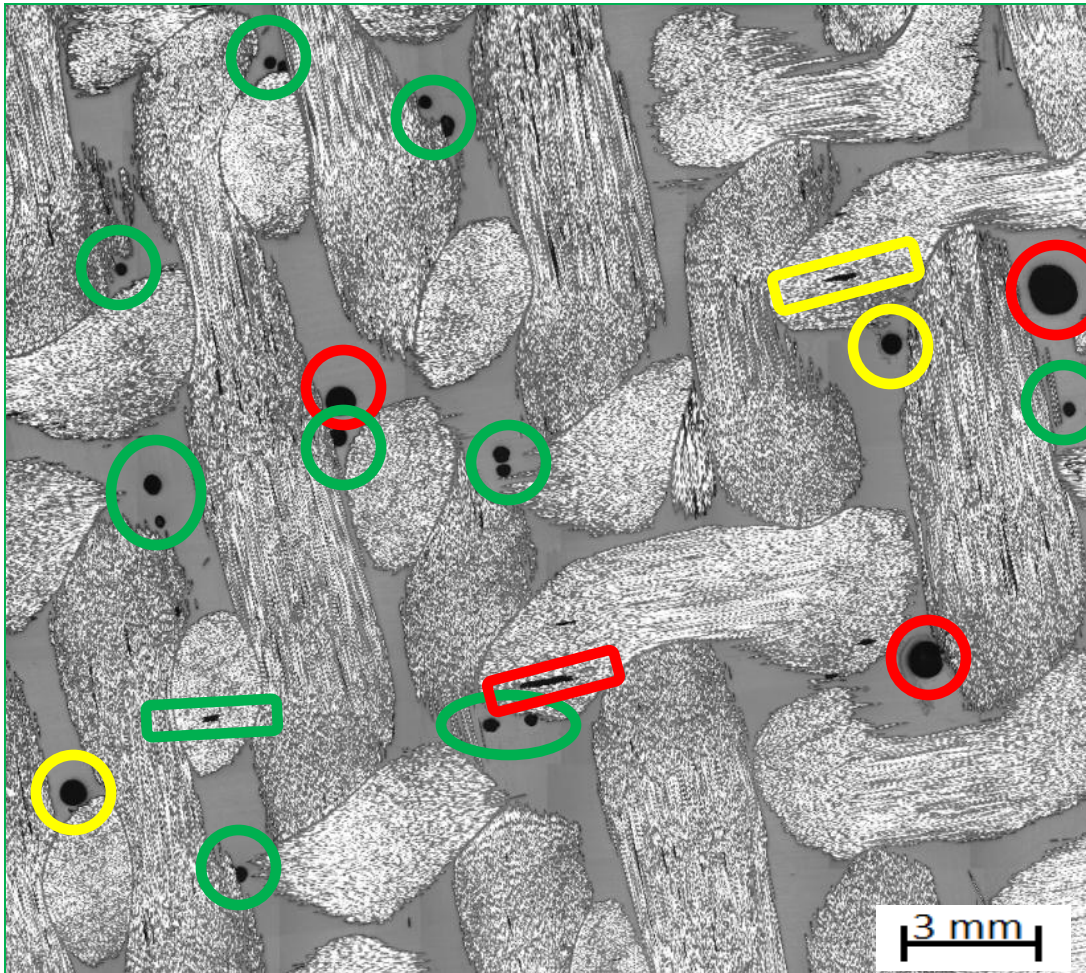
Elongated shape



- based on feret min



Classification



Rounded shape

Small: 10-20x voxel size

Medium: 20-30x voxel size

Large: > 30x voxel size

Elongated shape

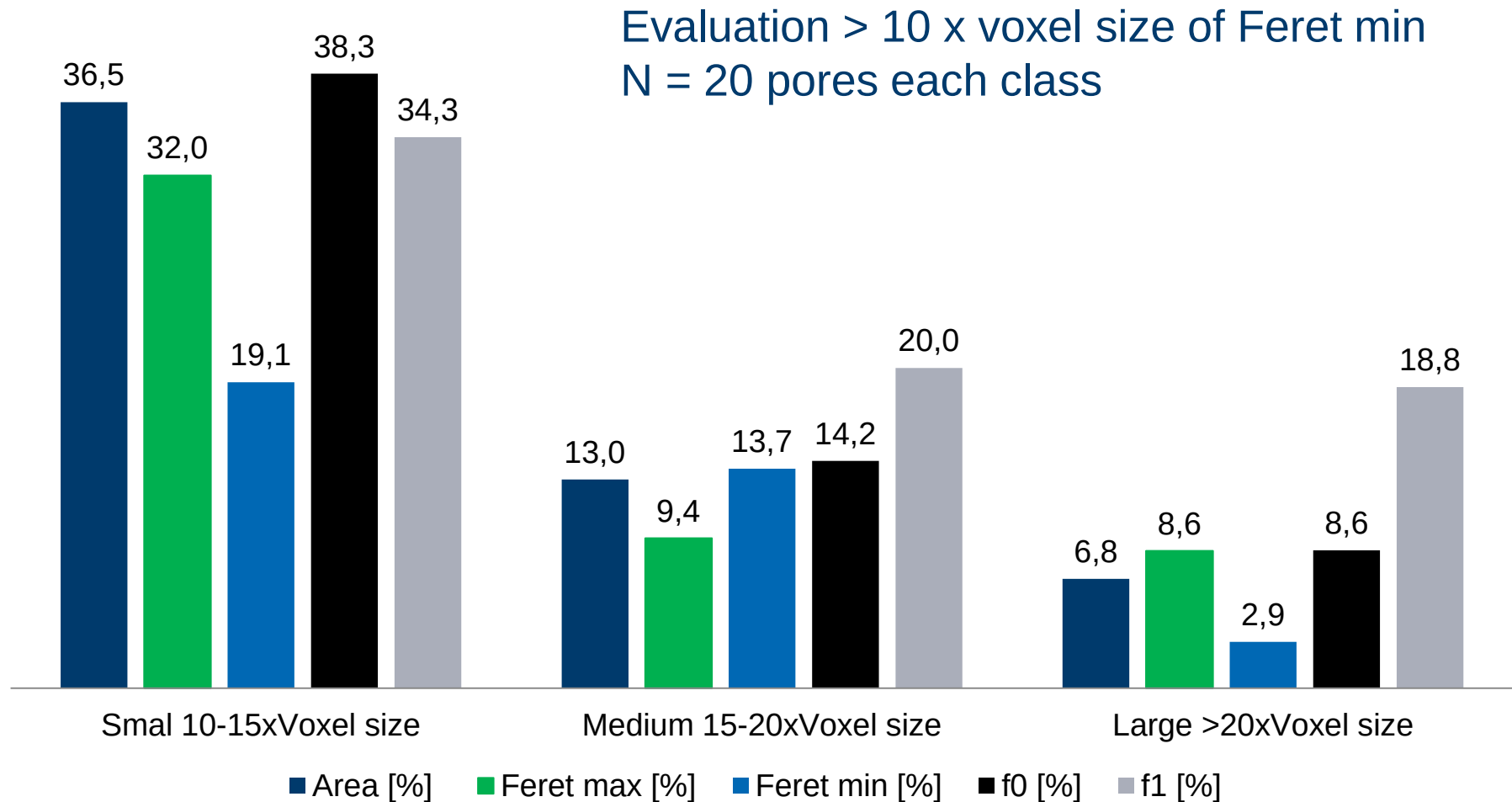
Small: 10-15x voxel size

Medium: 15-20x voxel size

Large: > 20x voxel size

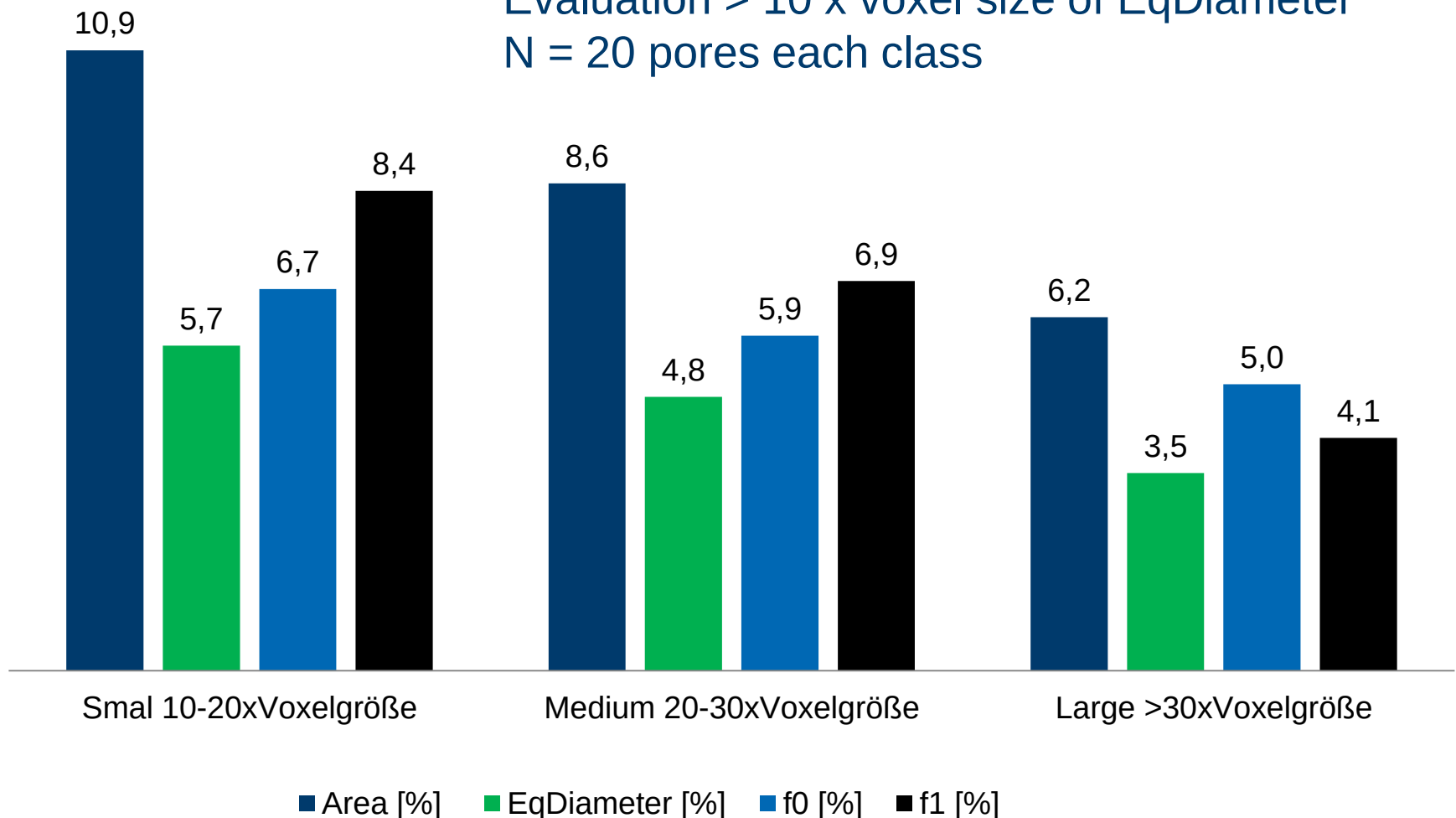
Results of Estimation for various types of samples

Average deviation of elongated shape



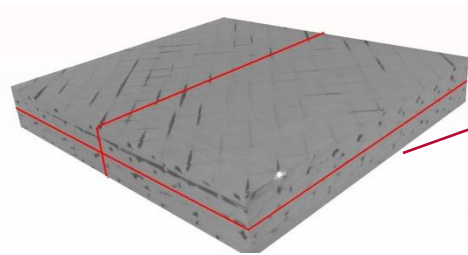
Average deviation of rounded shape

Evaluation > 10 x voxel size of EqDiameter
N = 20 pores each class

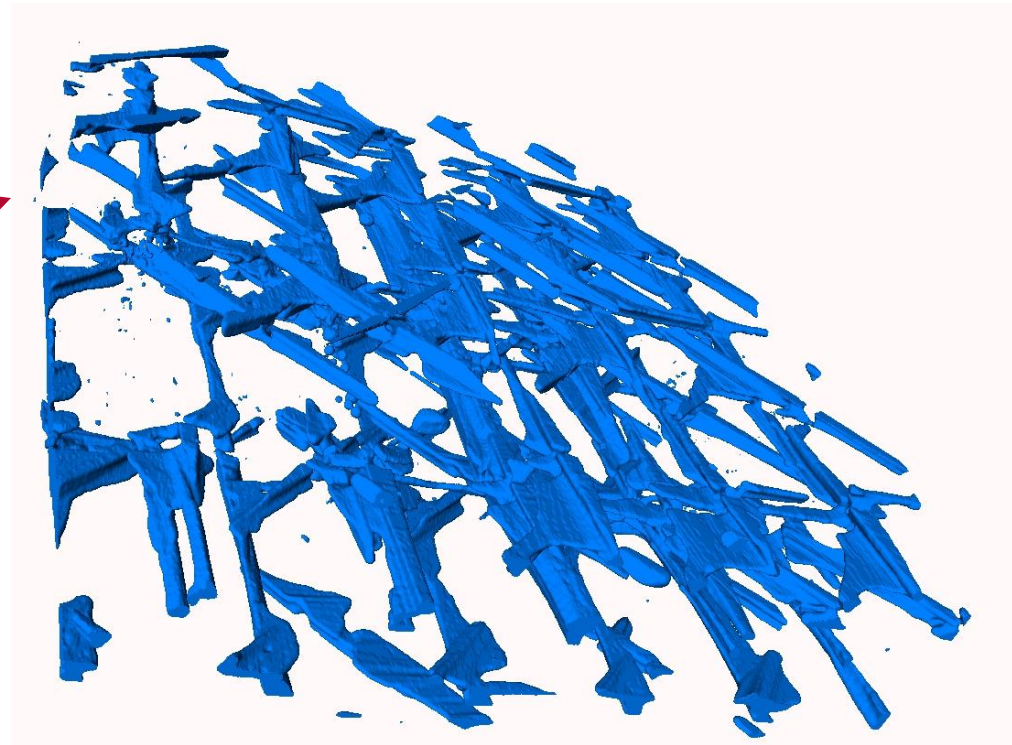


Future objectives

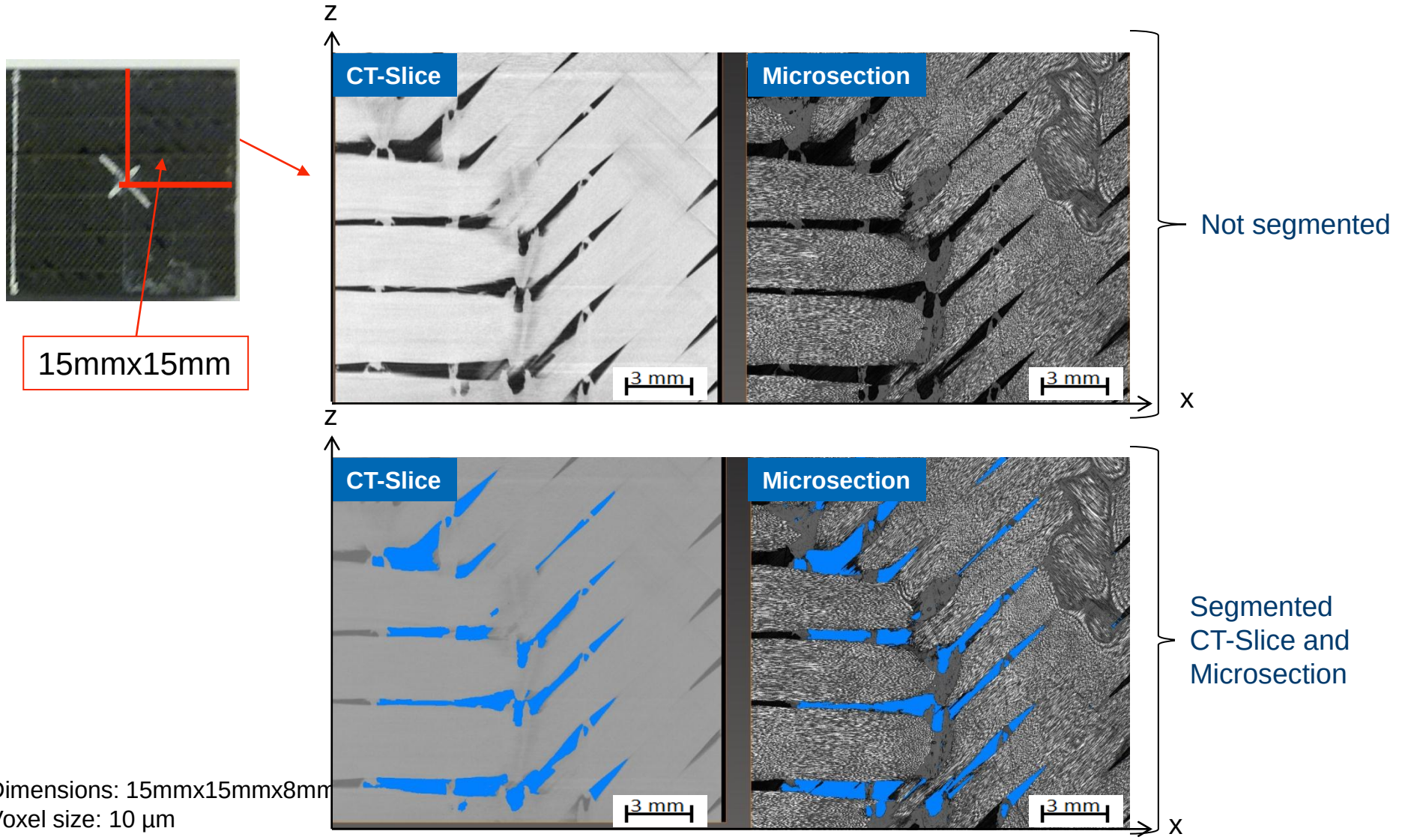
- Estimation of the:
 - distribution of pores 2D/ 3D
 - 3D-orientation

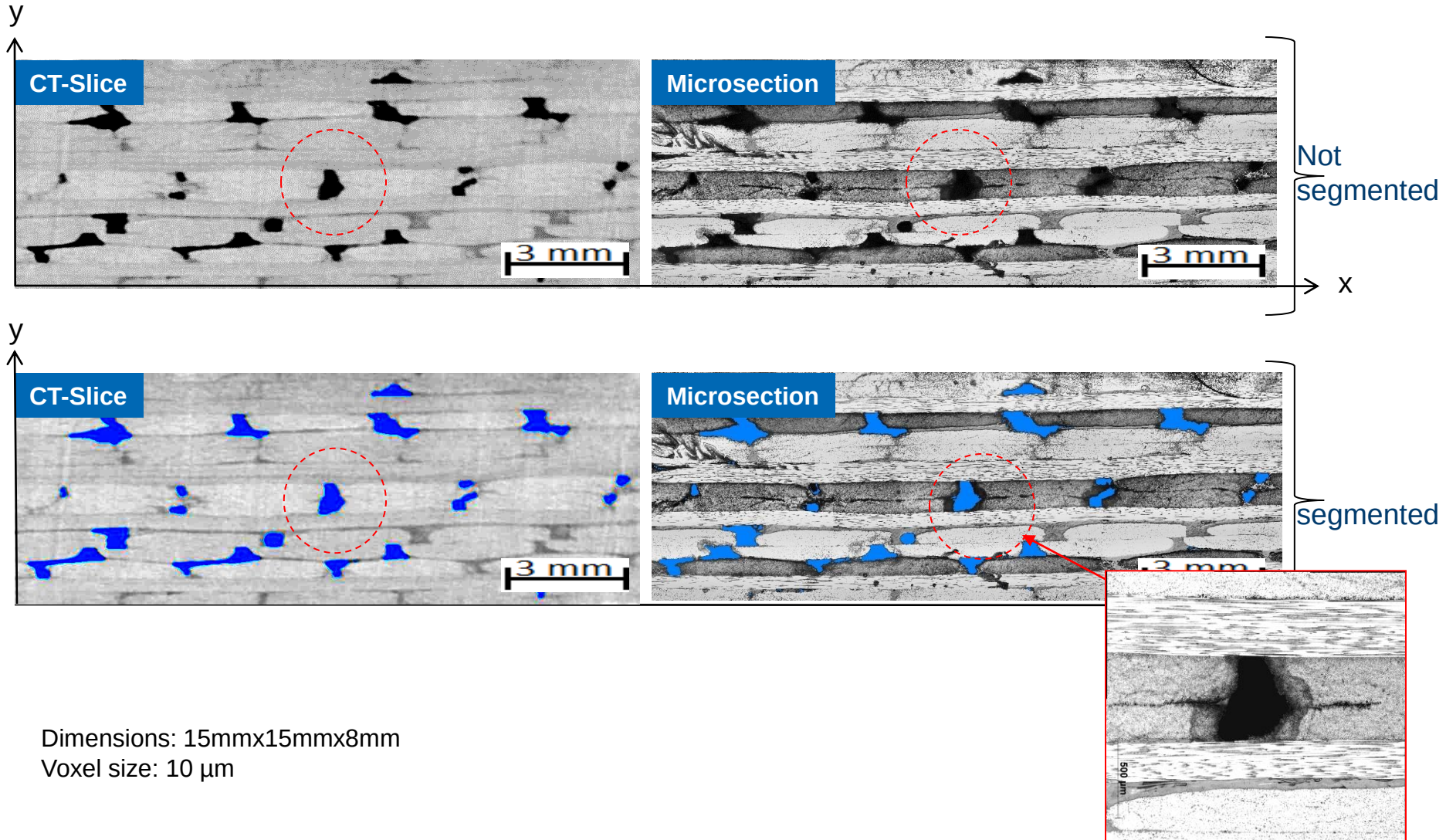


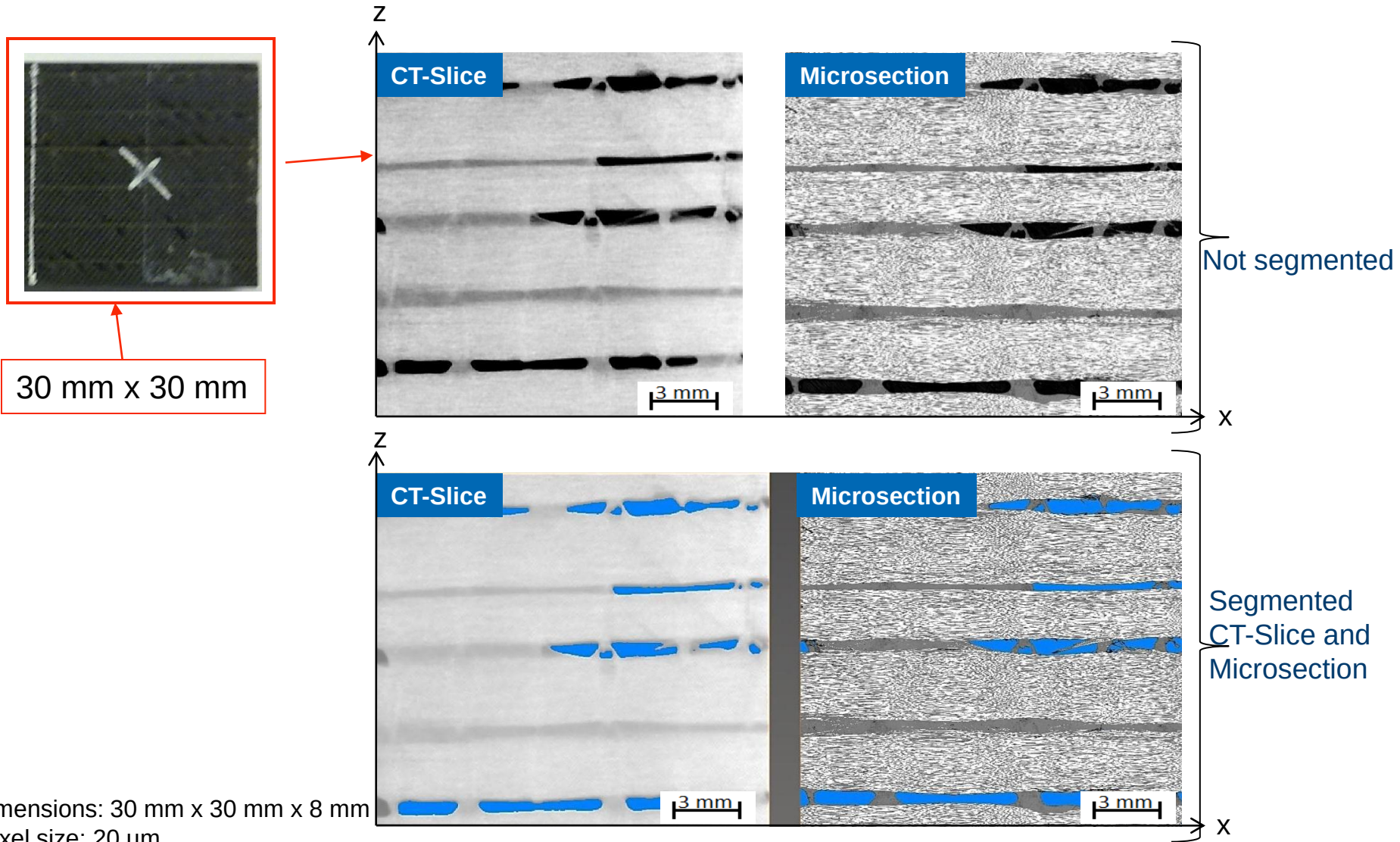
Dimensions: 15 mm x 15 mm x 4 mm
Voxel size: 10 μm



Many thanks for your attention!!!







Typical dimensions of pores in CFRP-samples

