# Validation of Failure of Long Fiber Thermoplastics by Digimat Analysis Coupled to Micro Computer Tomography

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# Cooperation partners


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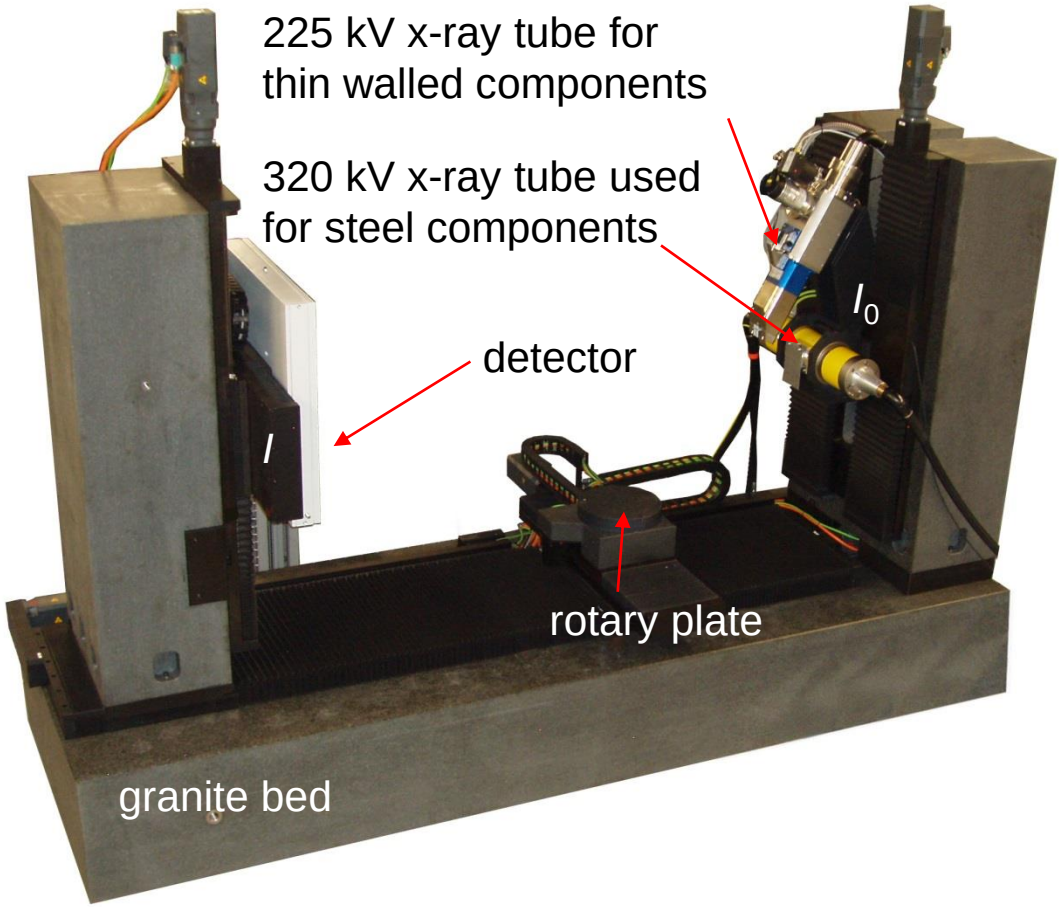
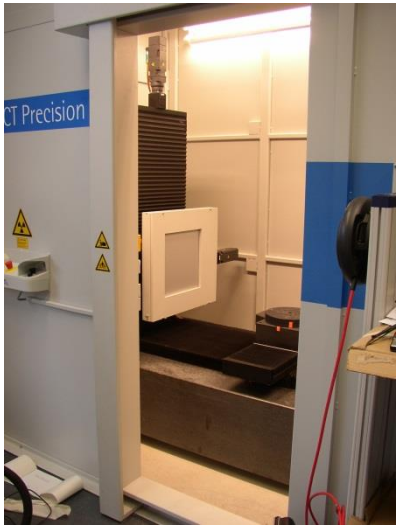
# Design of an Industrial µ-CT System

$I = I_0 \exp(-kd)$;
$I$: intensity at detector

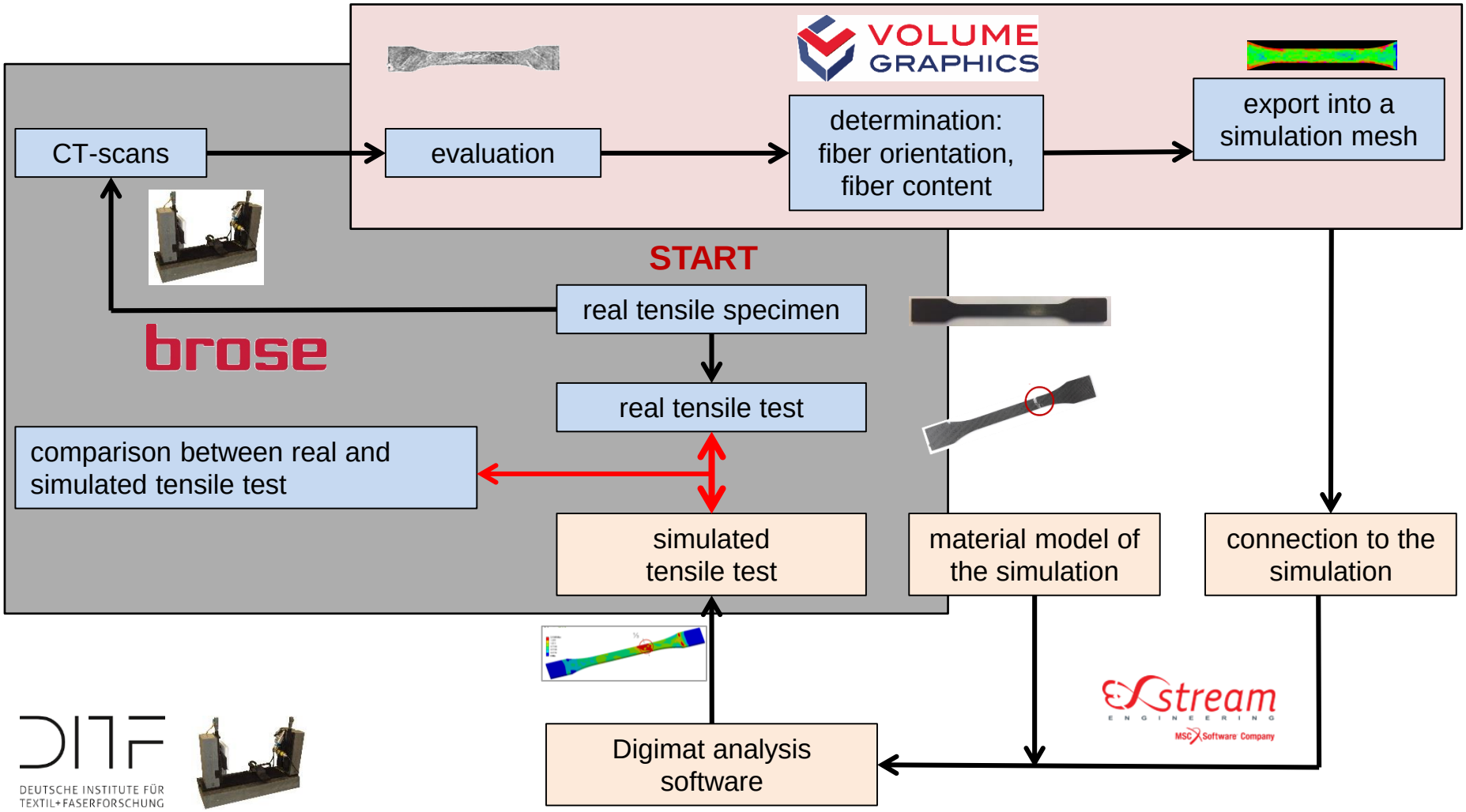


radiation protection cabin


µ-CT system at DITF in Denkendorf

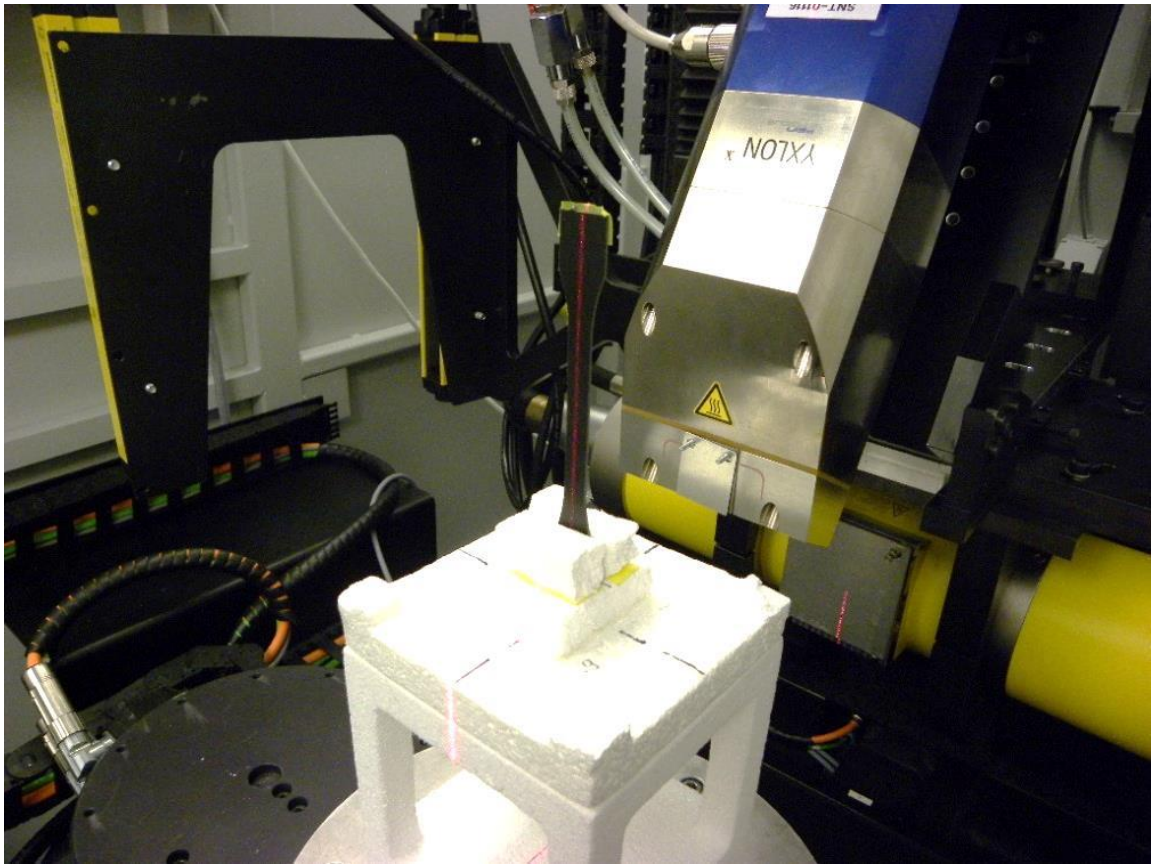
# Export of CT-data into Digimat Analysis Software




The high resolution scan was done by Hermann Finckh at DITF in Denkendorf

# Realization of the CT-Scan at Brose

- Positioning of the tensile specimen with a polystyrene holder
- Dimensions of the tensile specimen:
  - Height: 150 mm
  - Width: 10 mm
  - Thickness: 1.8 mm
- Complete tensile specimen was scanned **two** times in **seven** sub-scans (resolution: **12.5 µm; 50 µm**)
- Total scanning time: **30 h**
- Difficulty: **stability of the x-ray-tube over a period of 30 h**

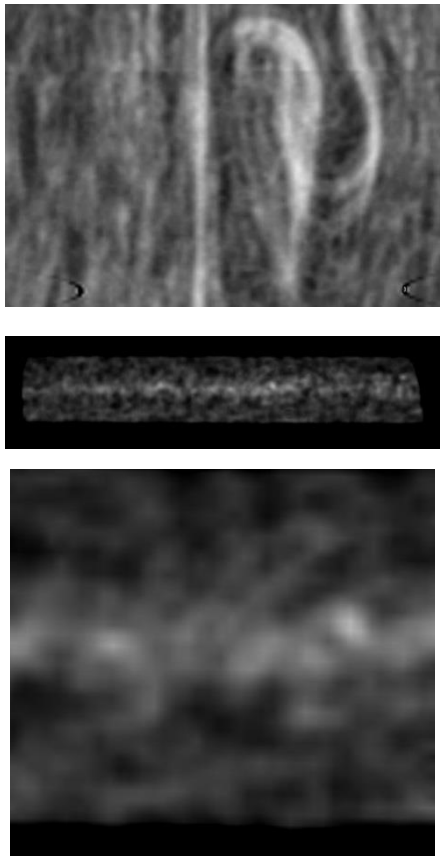


# Realization of the CT-Scan at DITF

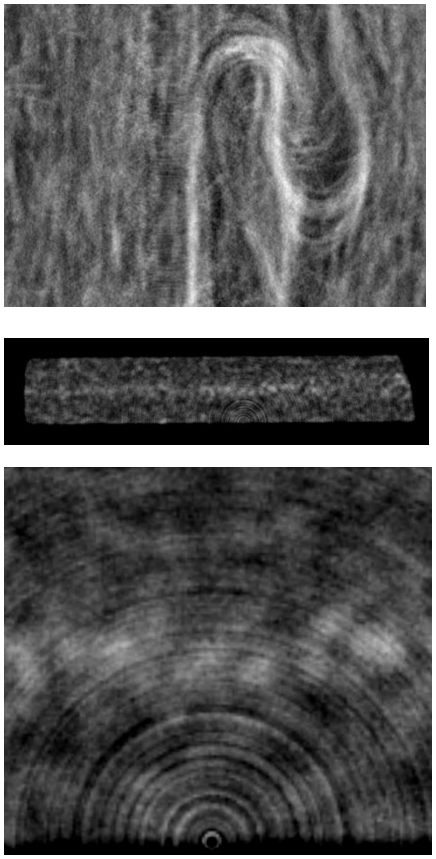
- Positioning of the tensile specimen with a mounting
- Dimensions of the tensile specimen:
  - Height: 150 mm
  - Width: 10 mm
  - Thickness: 1.8 mm
- Complete tensil specimen was scanned in **four sub-scans** (resolution: **12.5 µm**)
- Total scanning time: **8 h**
- Advantage of the CT at ITV:
  - **Machine is designed for analysis of fiber composite material**

# Comparison of Different CT Scans

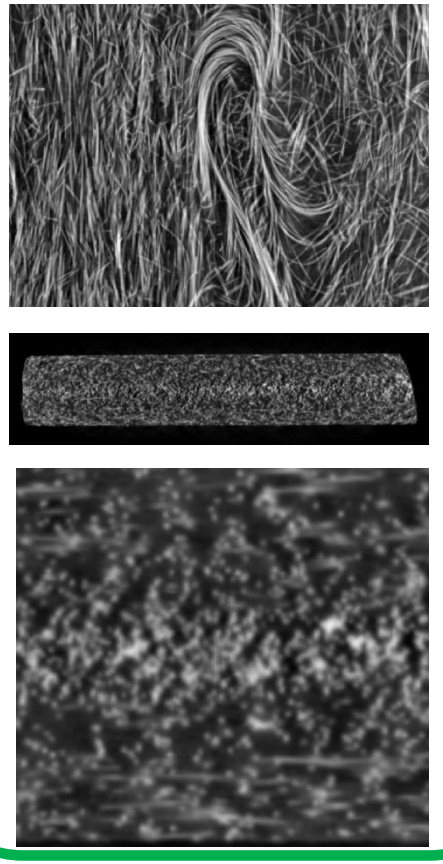
First Scan 50 µm
Brose, Low resolution



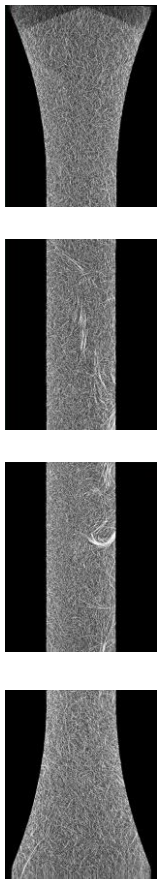
Second Scan 12,5 µm
Brose, High nominal resolution,
but noise and center artefacts



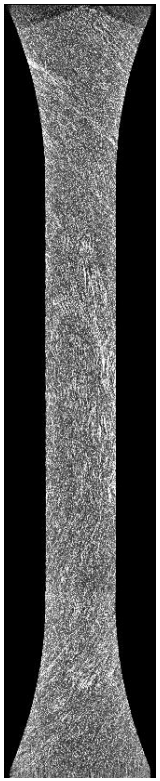
Third Scan 12,5 µm
DITF, High resolution,
low noise, no artefacts



# Analysis of CT Data using VGSTUDIO MAX



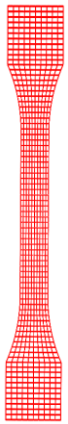
merge data sets into one



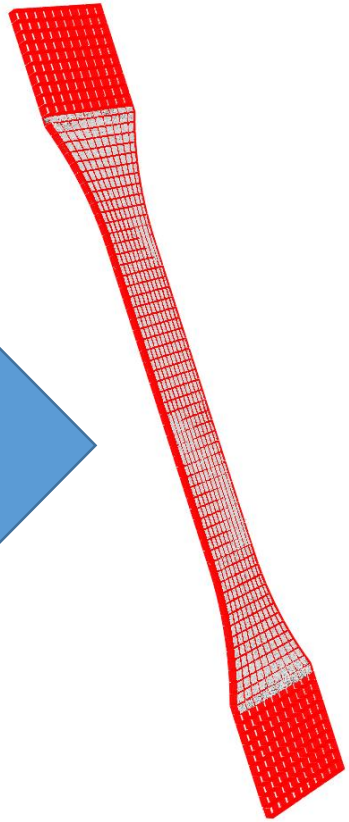
1 CT data set

import CAD

register CT data, CAD and mesh into one coordinate system

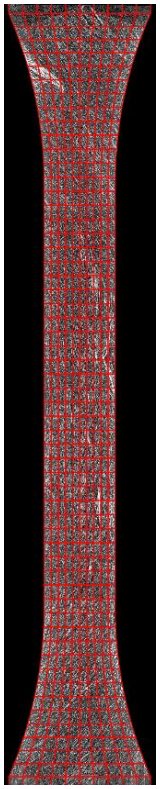


import sumulation mesh

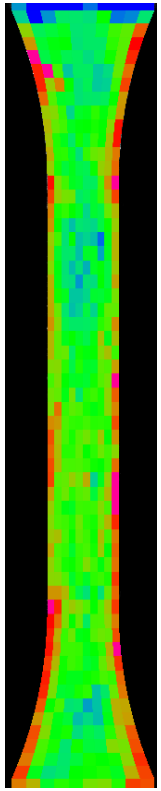


3D scene with CT data, CAD and mesh

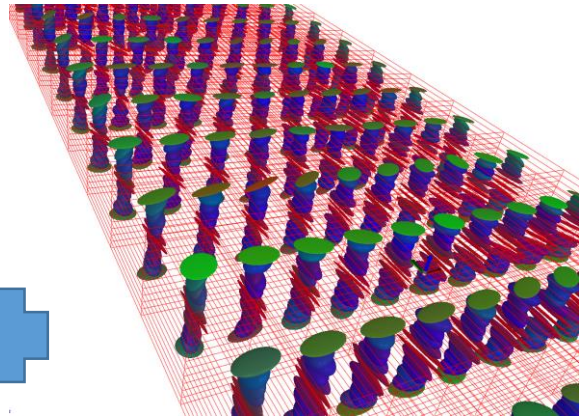
# Analysis of CT Data using VGSTUDIO MAX

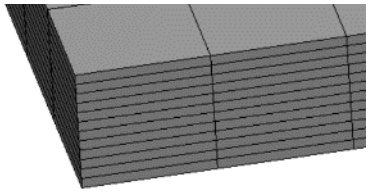


Calculate orientation tensor and fiber content for each mesh cell

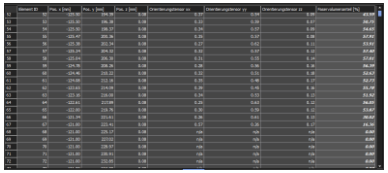


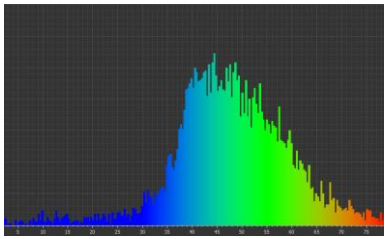
false color coding of fiber content

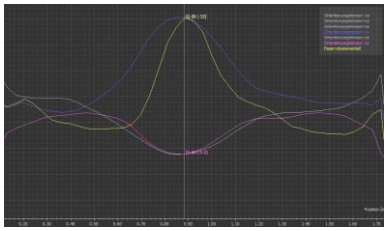




3D visualization of orientation tensor as ellipsoid





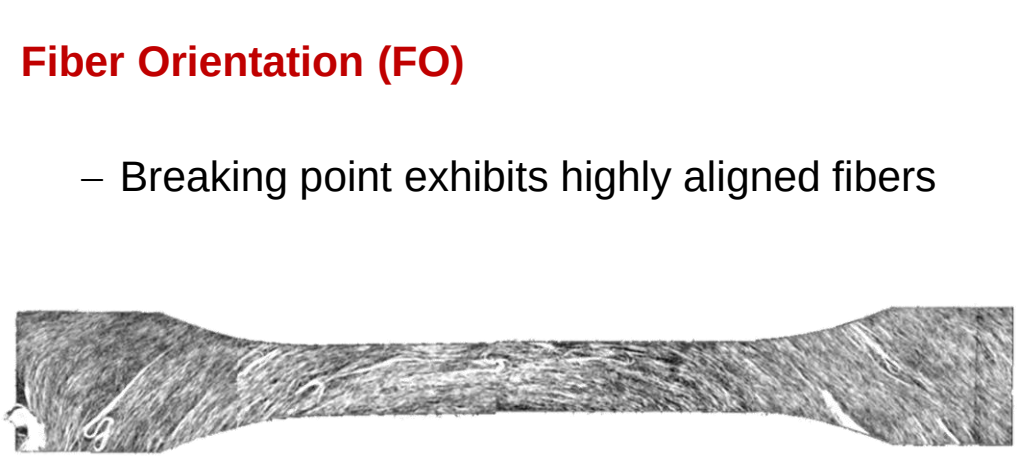


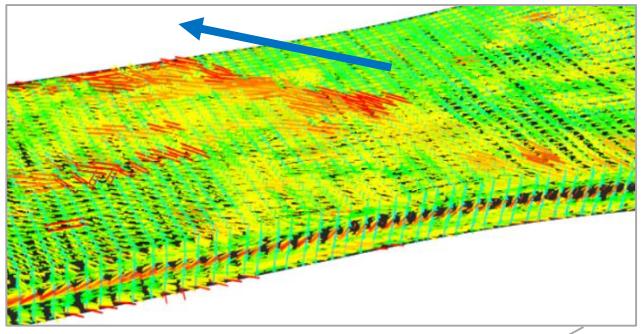
Tables, Histograms, Plots and many more

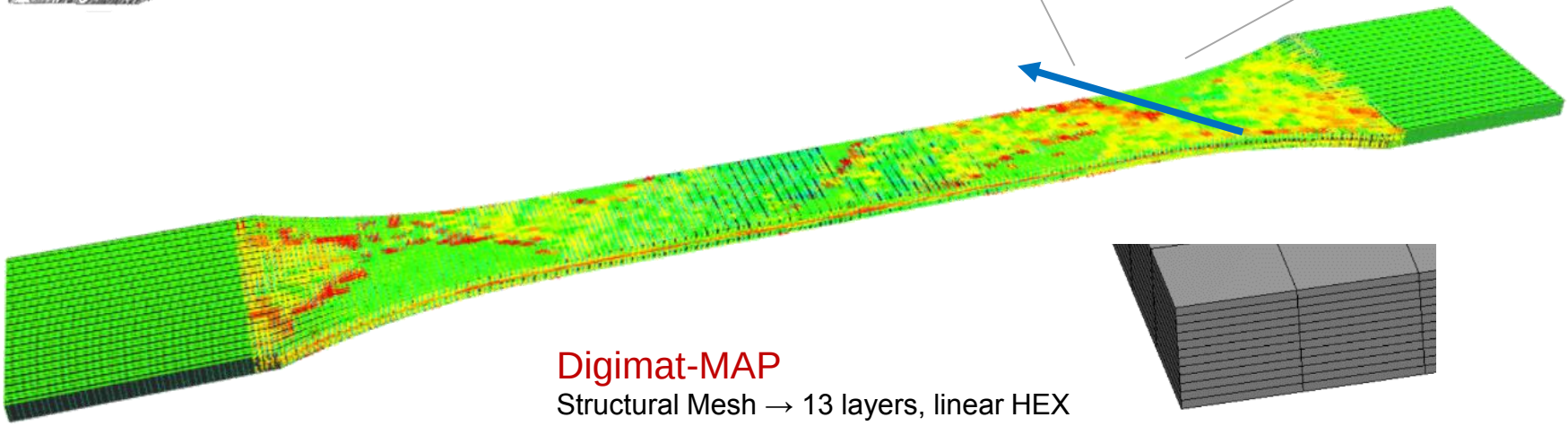
CSV Export of all results

# Microstructure: after Import of VG Data into Digimat Software

- **Fiber Orientation (FO)**
  - Breaking point exhibits highly aligned fibers





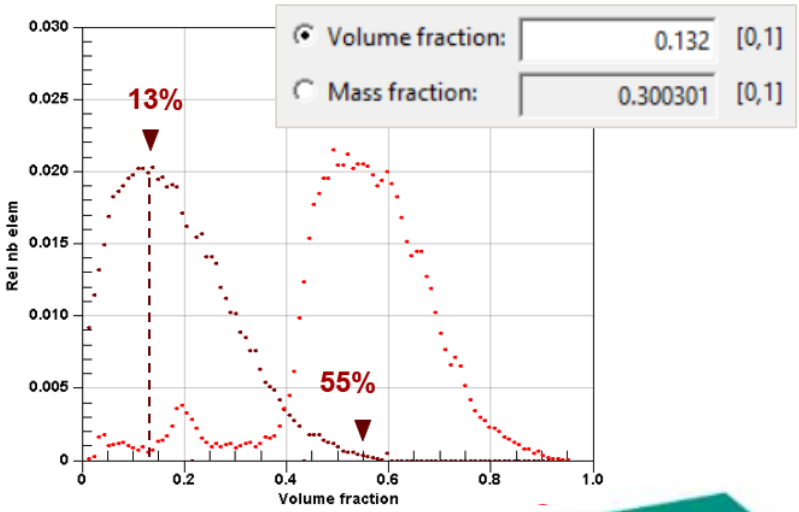


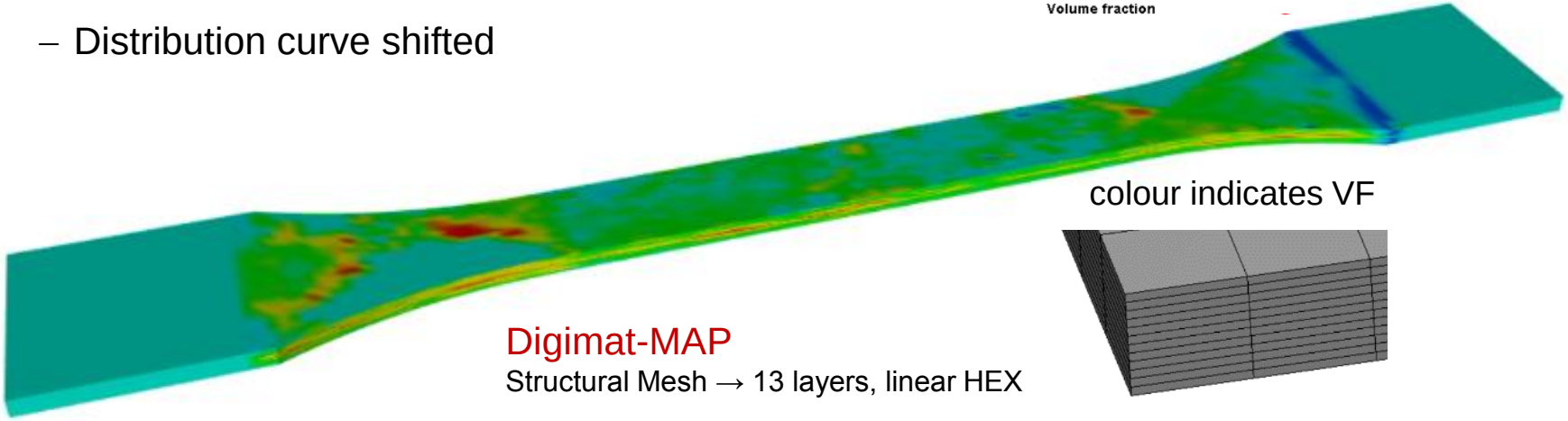


Digimat-MAP
Structural Mesh → 13 layers, linear HEX

# Microstructure

- **Volume Fraction (VF) of Fibers**
  - Distribution over tensile specimen
    - High values in middle layer
  - First over-estimation by CT
    - Due to value in grey scale analysis
  - Distribution curve shifted



colour indicates VF



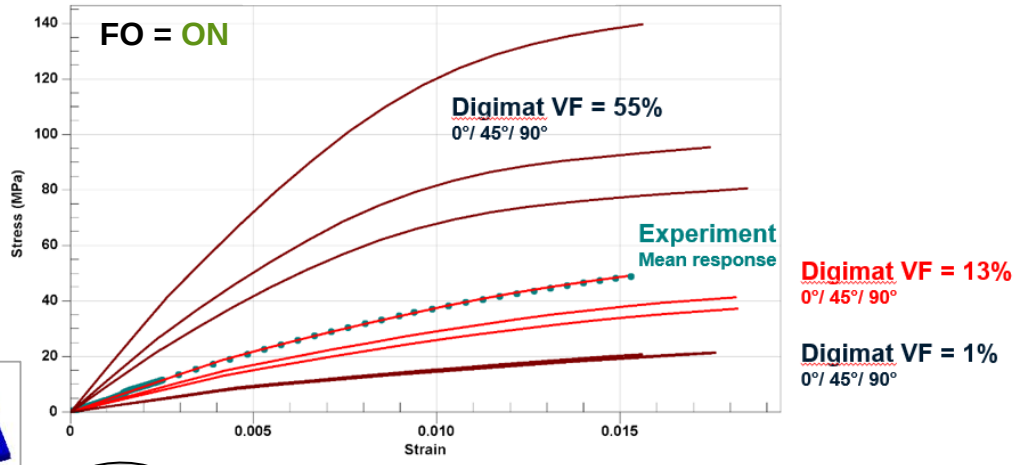
Digimat-MAP

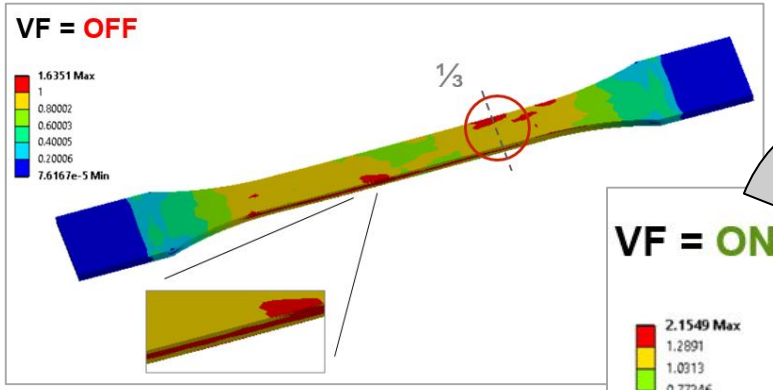
Structural Mesh → 13 layers, linear HEX

# Simulation

- **Failure**
  - **FO = ON**
  - Good prediction of **failure location** based on complete CT data

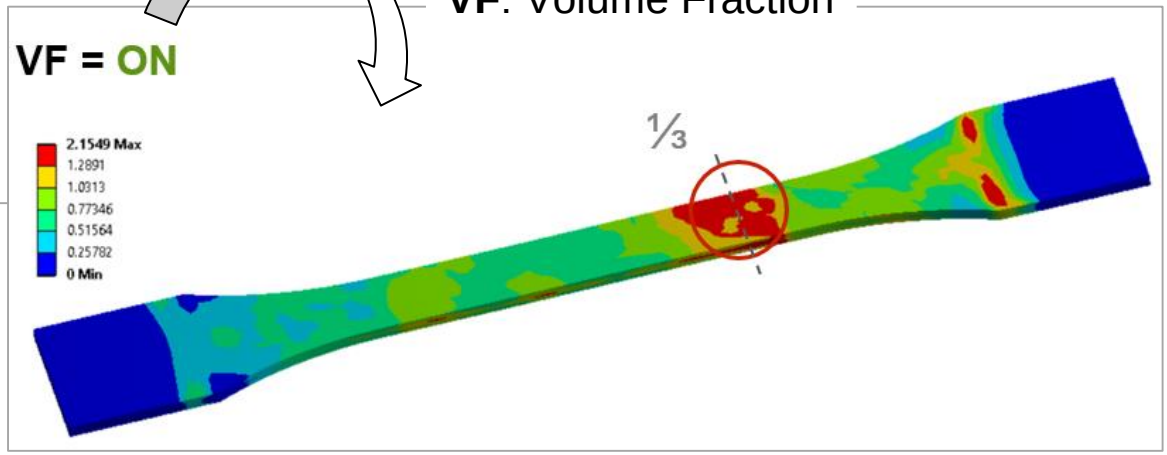
Existing Material Model



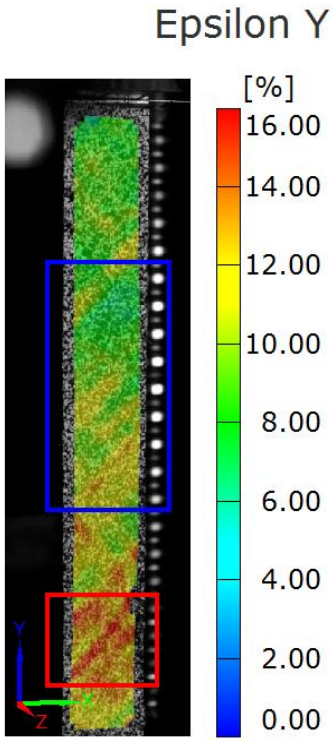




- Without VF failure still arises from the mid-plane

**VF**: Volume Fraction



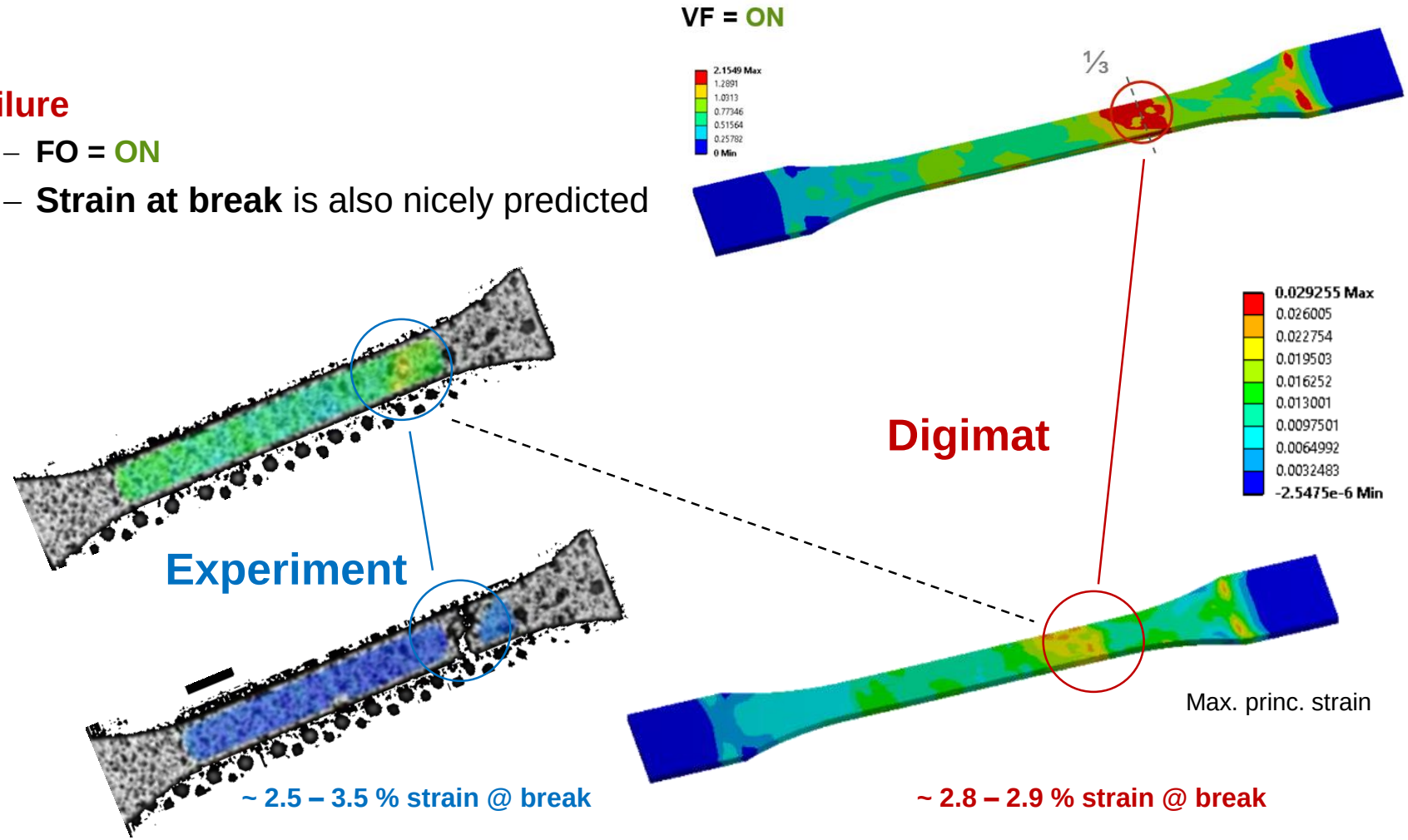
# Optical Strain Measurement




- Contactless and material independent measurement
- Optical 3-D-deformation- and  video analysis
- Strain measurement in the measuring range from 0.01 % up to >100 %

# Simulation

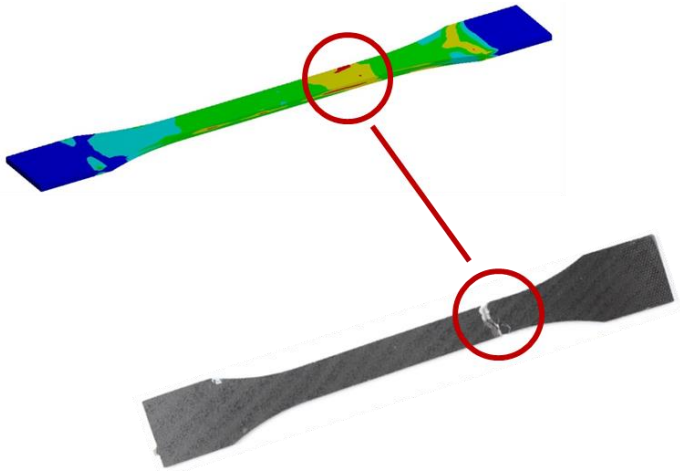
- **Failure**
  - **FO = ON**
  - **Strain at break** is also nicely predicted



# Summary

- For simulation of failure a high resolution CT-scan with a good signal-noise-ratio and without circular artefacts is necessary
- The export of the local fiber orientation information and fiber content is possible, but time consuming

- Digimat proves to be PREDICTIVE for failure of LFT material
  - **Based on OT + VF from µ-CT**
  - **Failure location**
  - **Strain at break**



# Thank you for your attention!