Translaminar Fracture Analysis in Hybrid Fibre-Reinforced Composites through 4D in-situ Synchrotron Tomography

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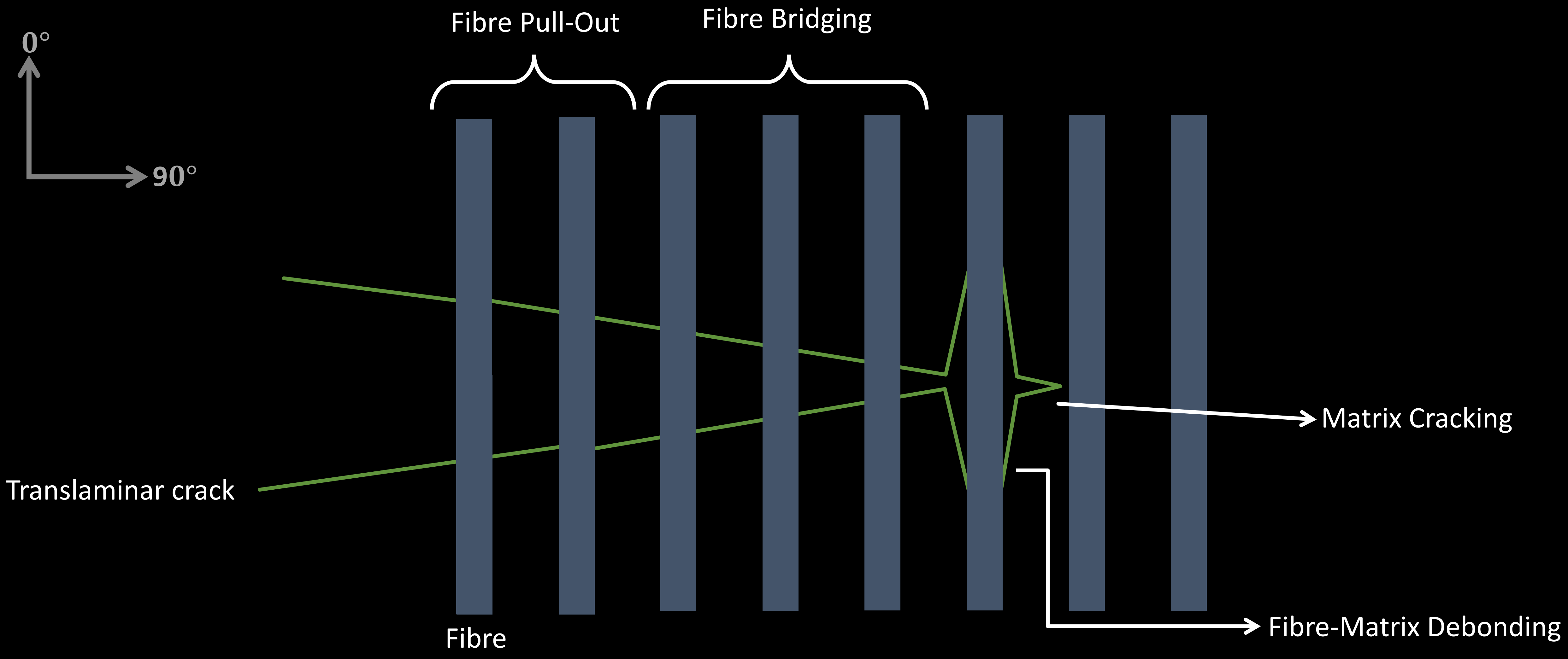
Translaminar Fracture: Why Do We Care?



Goal & Objectives

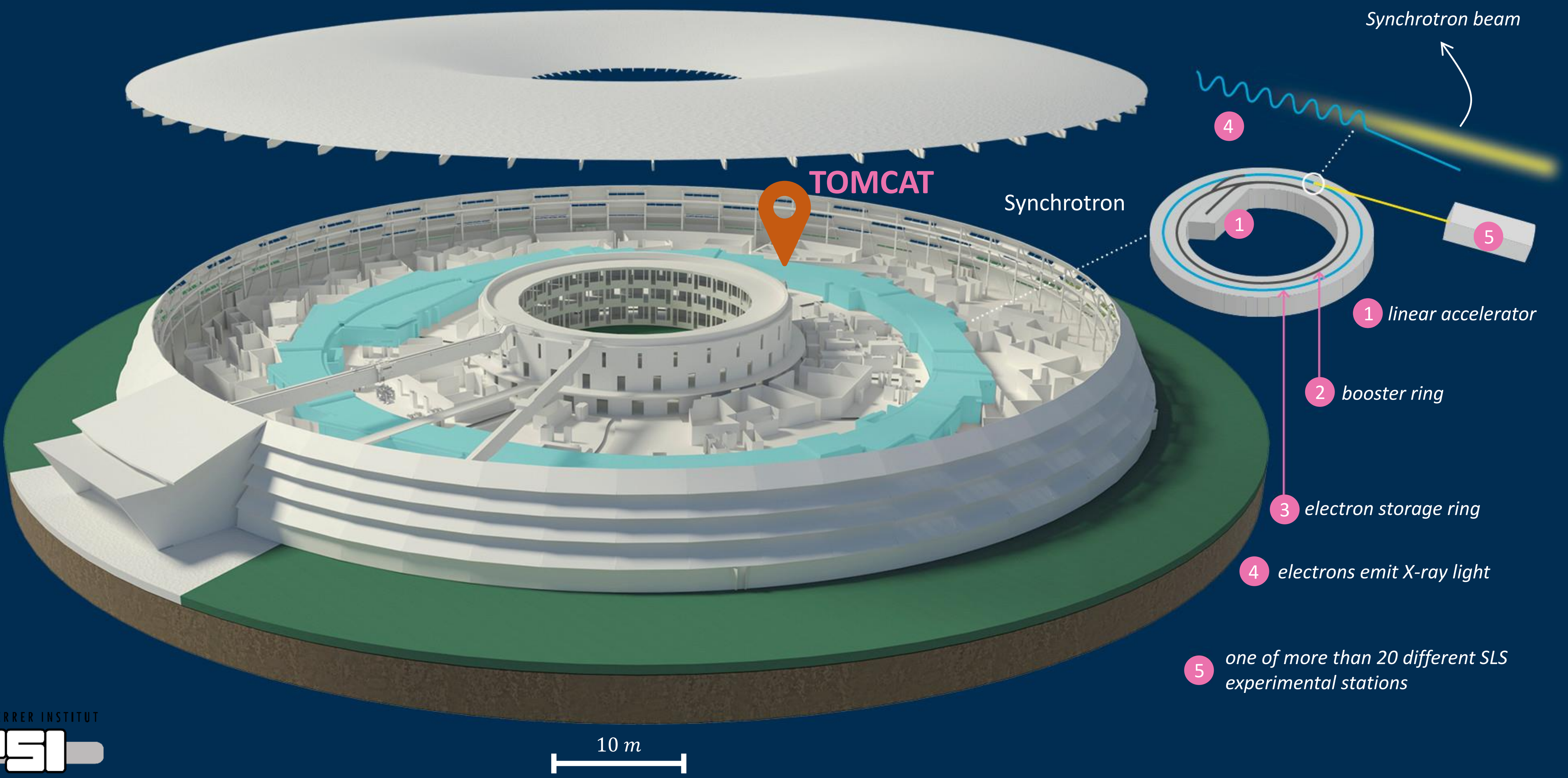
Goal:

To better understand translaminar fracture crack propagation at the microscale.

Objectives:

- To design a new mini compact tension specimen that:
  - Is geometrically suitable for 4D synchrotron radiation computed tomography,
  - Can yield stable crack propagation.

3D View: Swiss Light Source SLS



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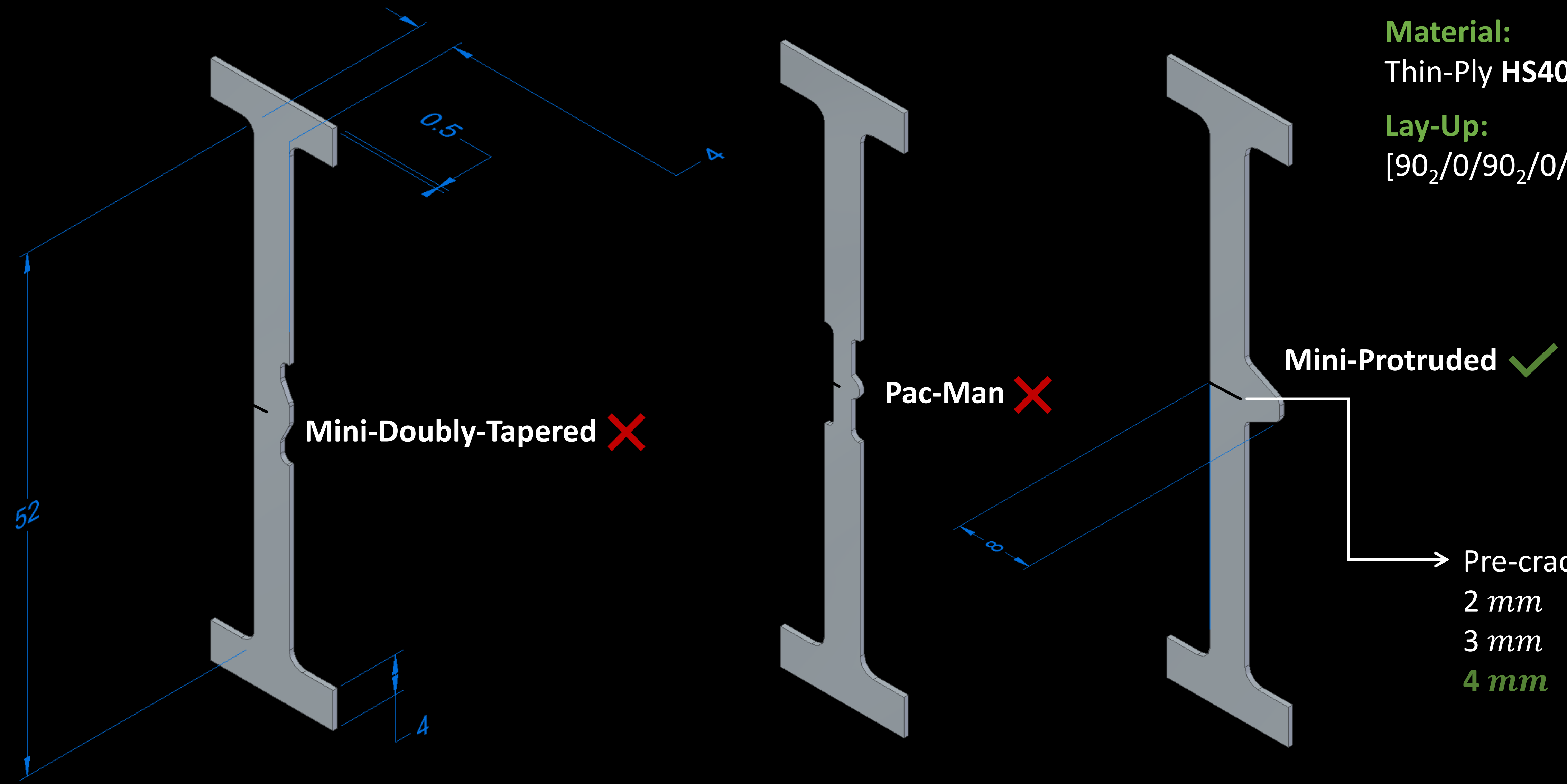
Compact Tension Experiments: Specimen Design

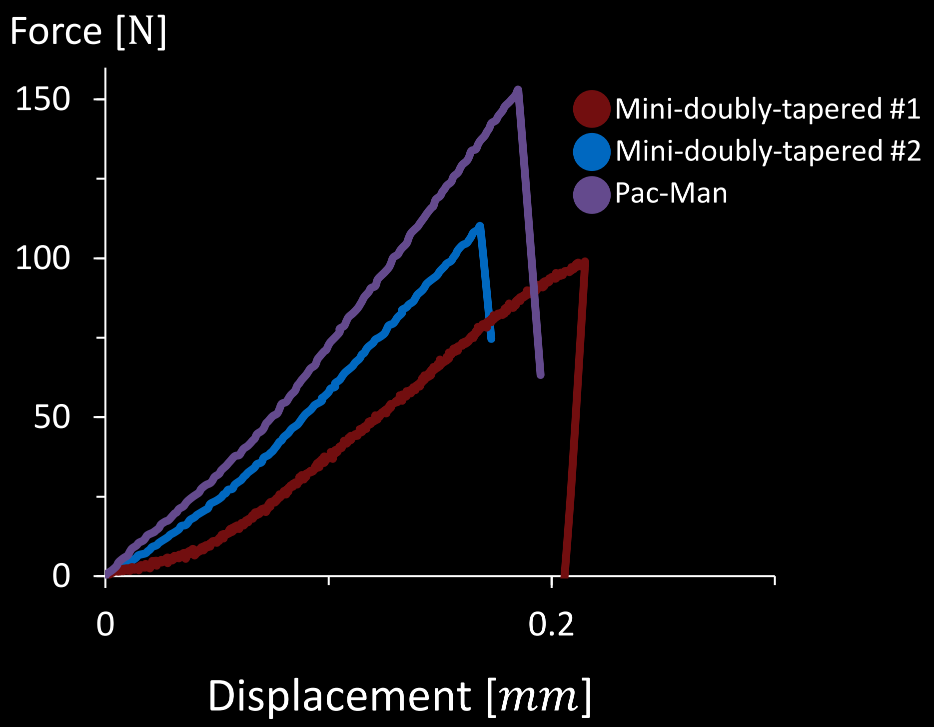
Material:
Thin-Ply **HS40-736LT**

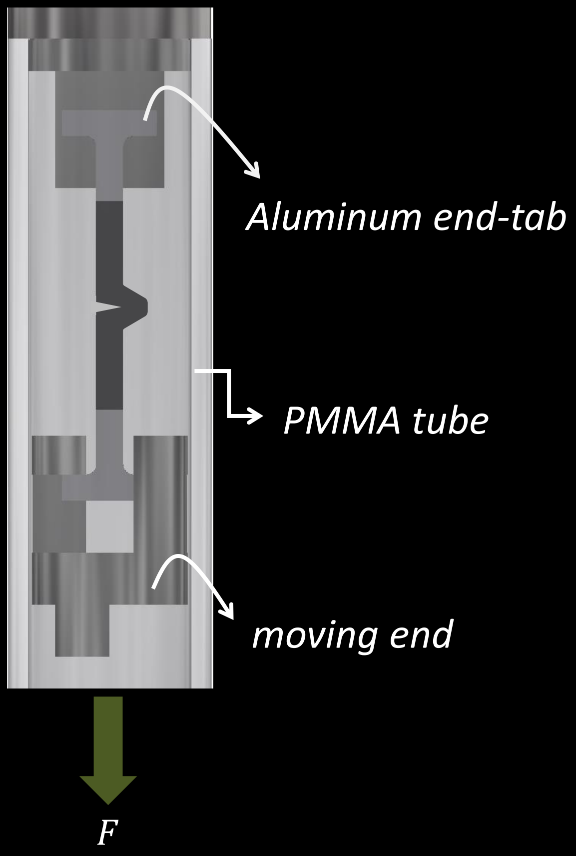
Lay-Up:
$[90_2/0/90_2/0/90_2/0/90_2]$

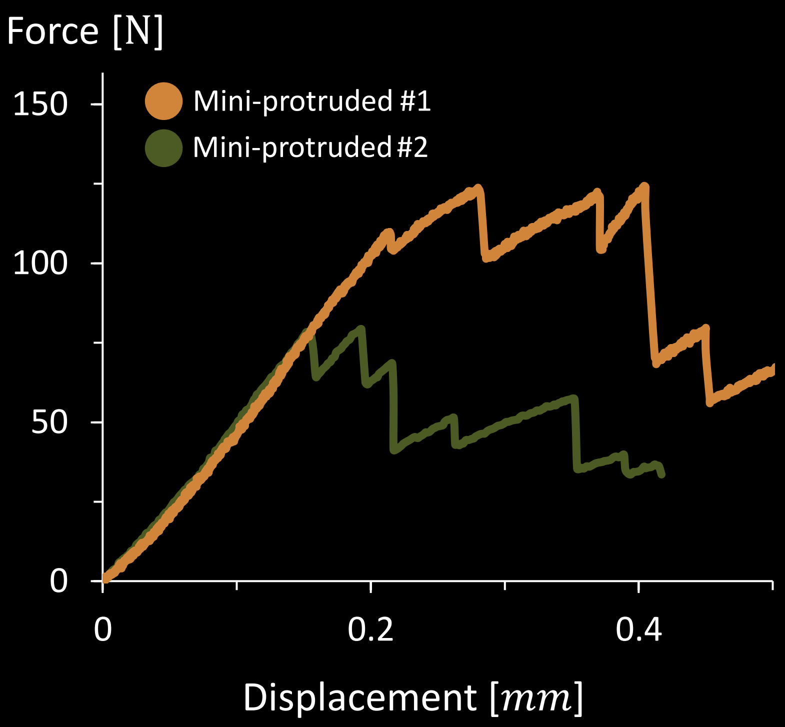


Pre-crack lengths:
$2\ mm$
$3\ mm$
$4\ mm$

Compact Tension Experiments: F–δ Results

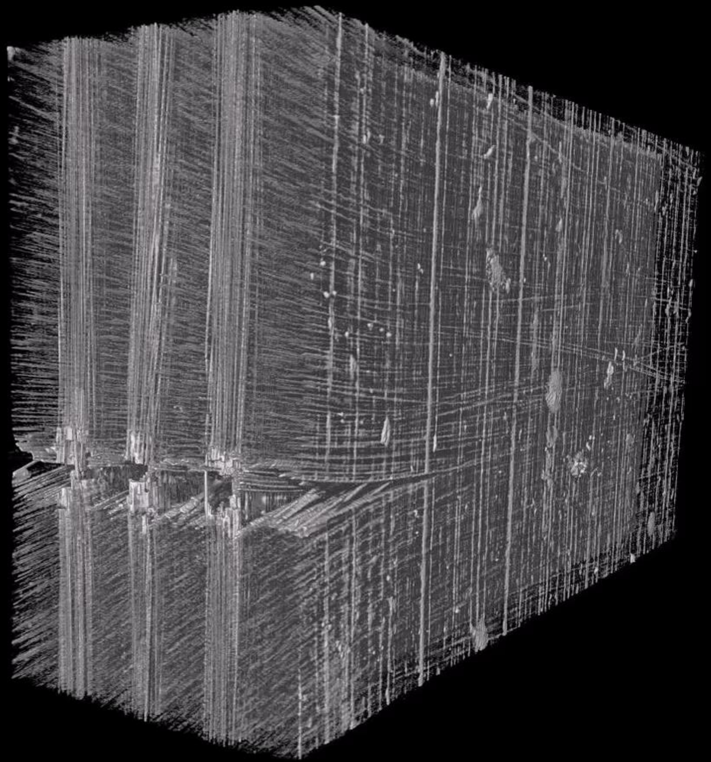


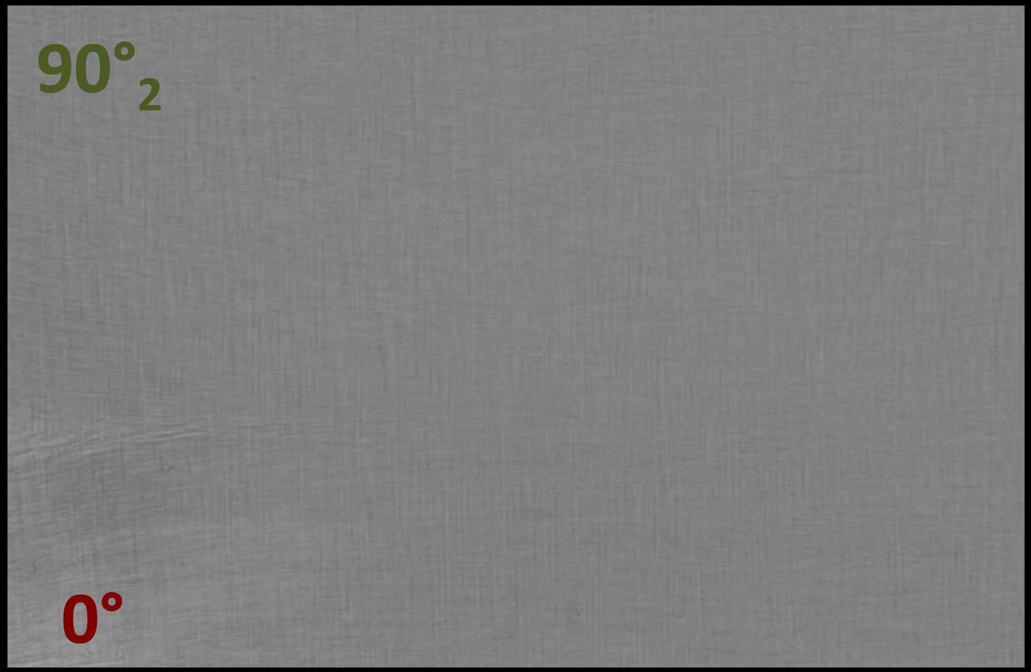




Voxel size **800 *nm***
GigaFRoST camera as the detector
polychromatic beam (energy = 24 keV)

3D & 2D Slices





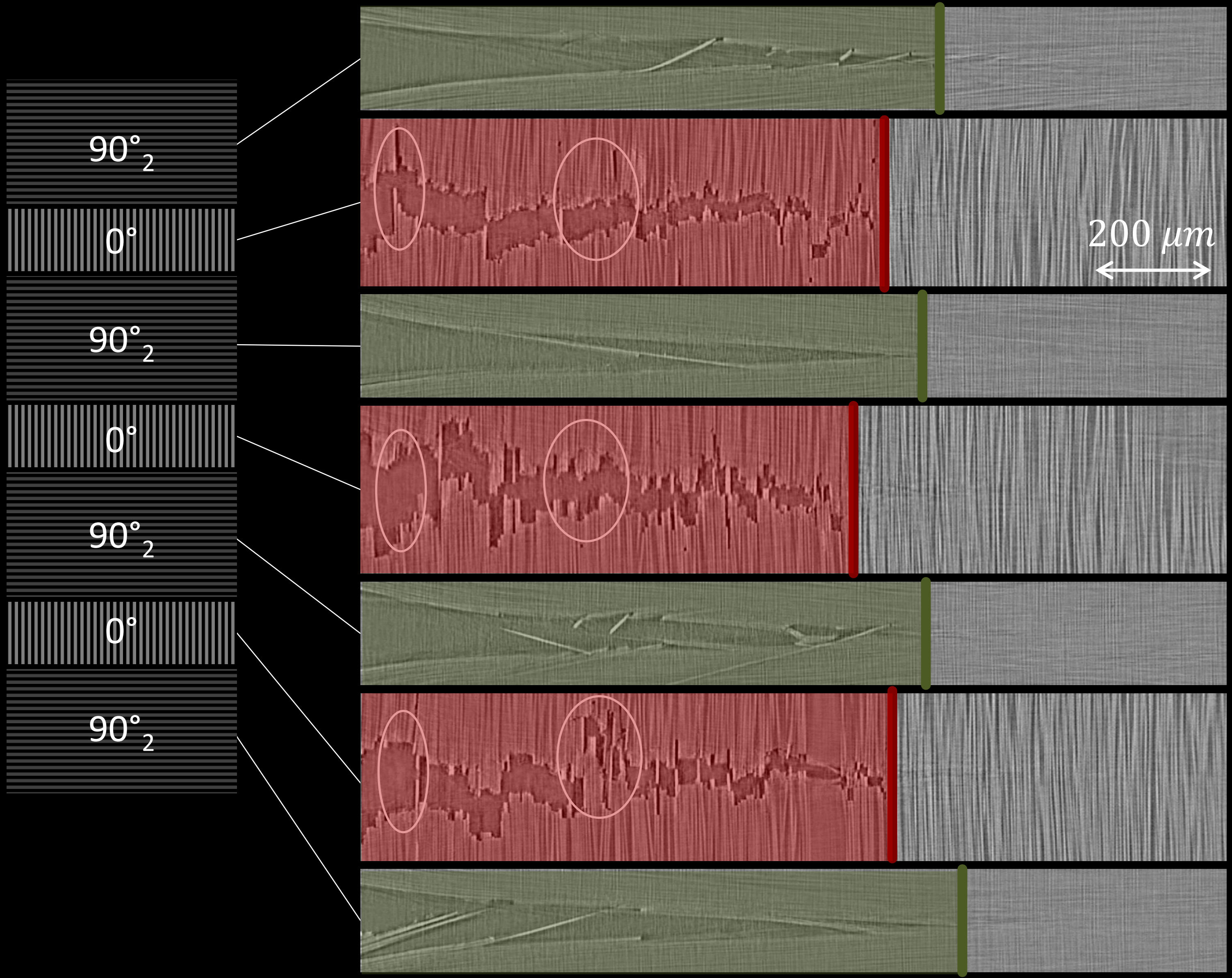
$[90_2/0/90_2/0/90_2/0/90_2]$

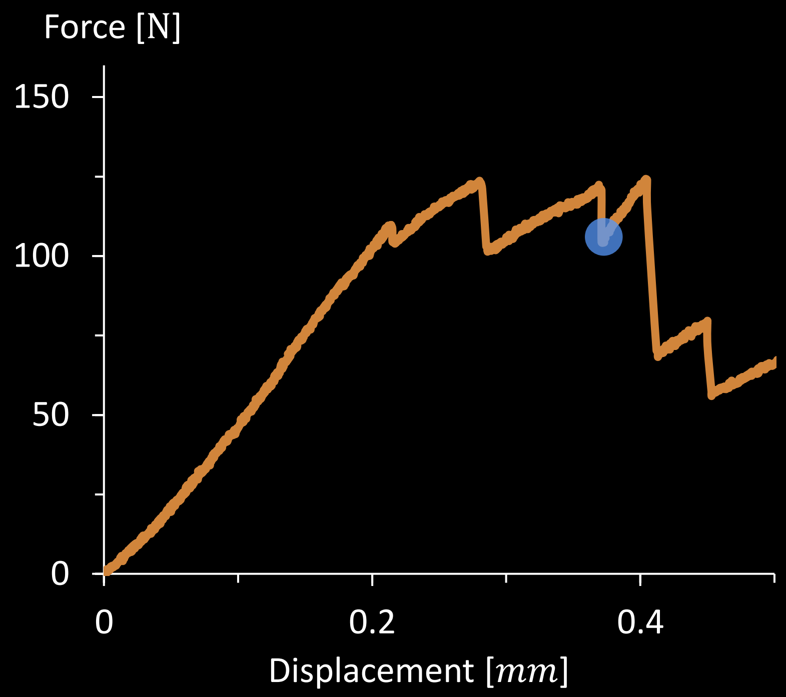
250 μm

Scans reconstruction using SLS in-house absorption-based algorithm (Gridrec)

F. Marone et al. 2012

Complex Fracture Morphology

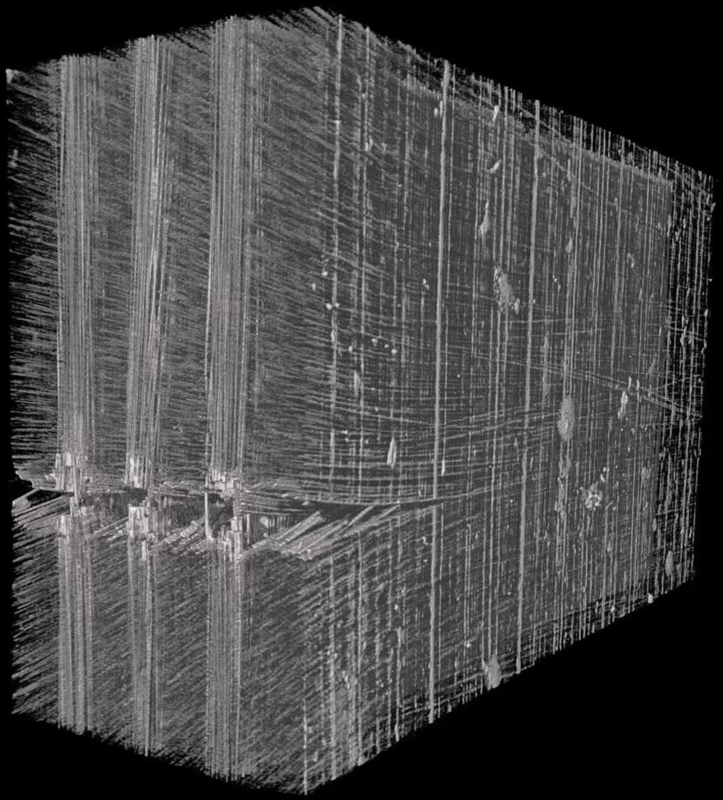


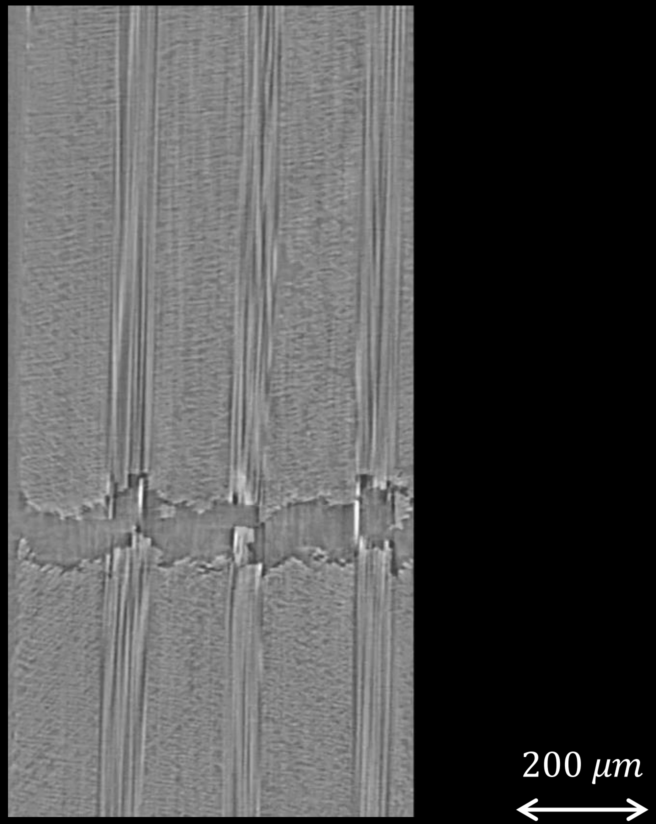


Detailed pull-out characterisation

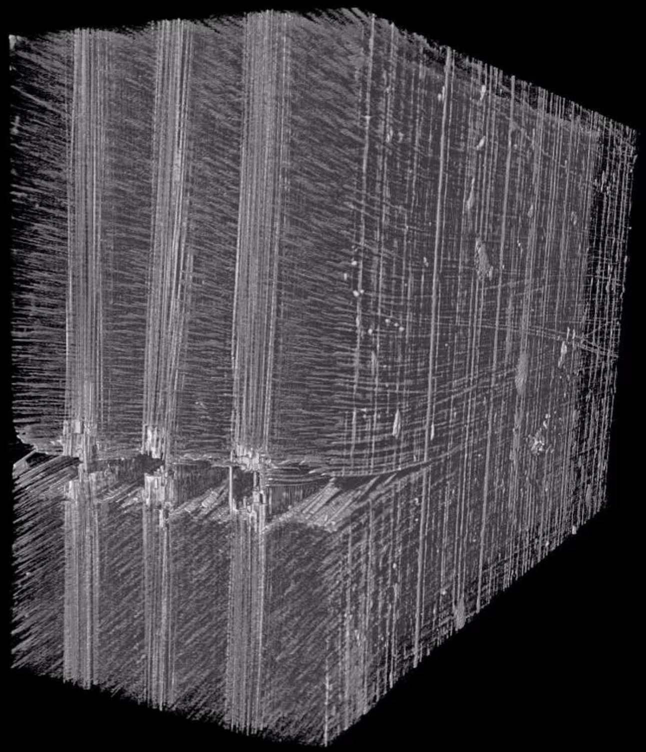
90° cracks ahead of 0° cracks

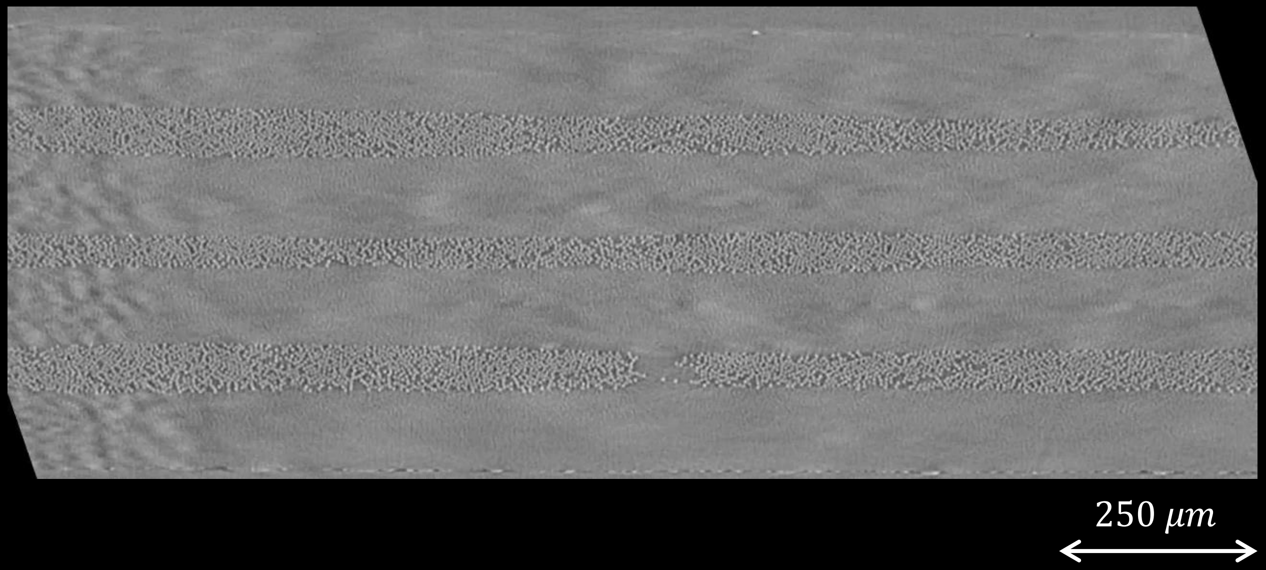
3D & 2D Slices



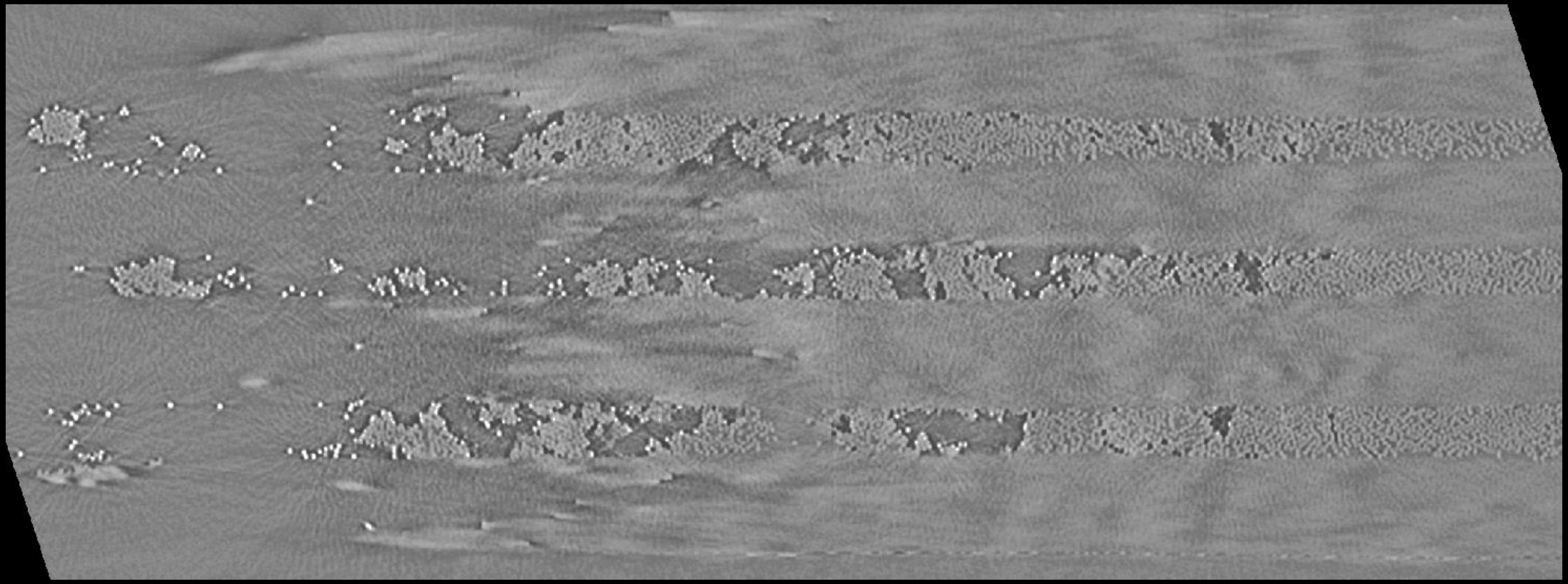


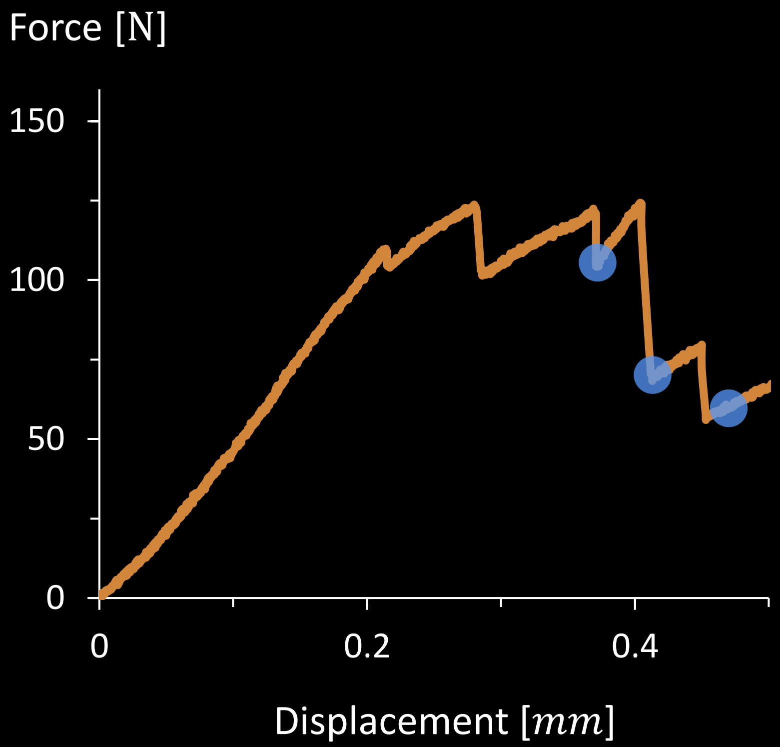
3D & 2D Slices



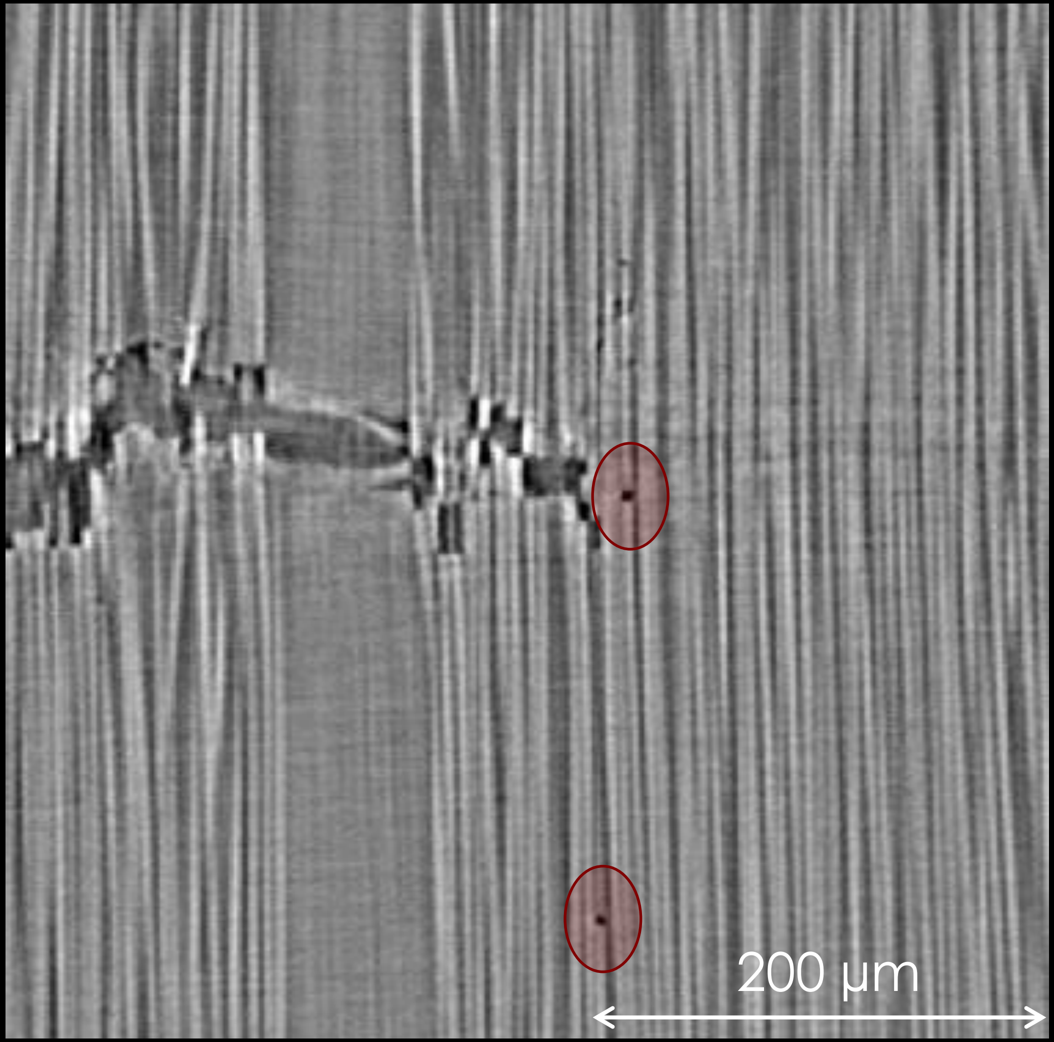


3D & 2D Slices: Various Load Levels

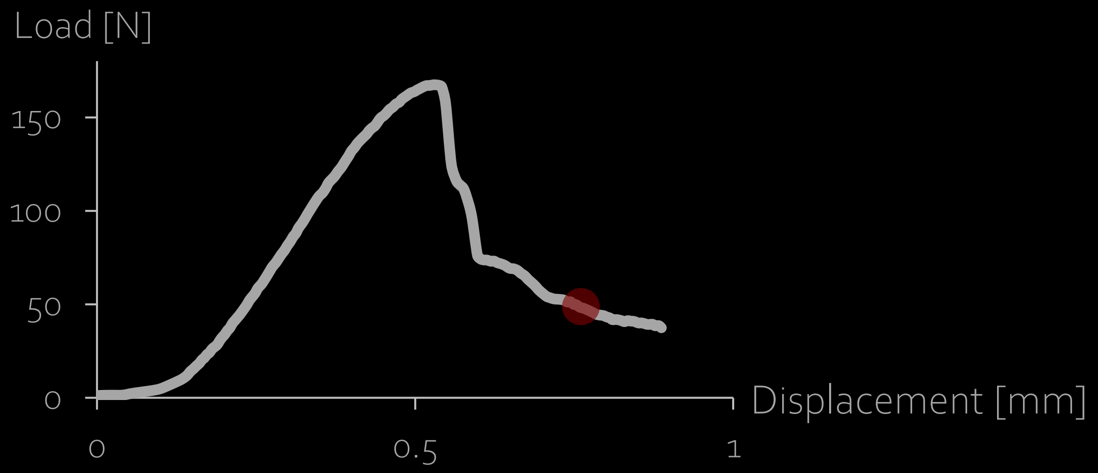


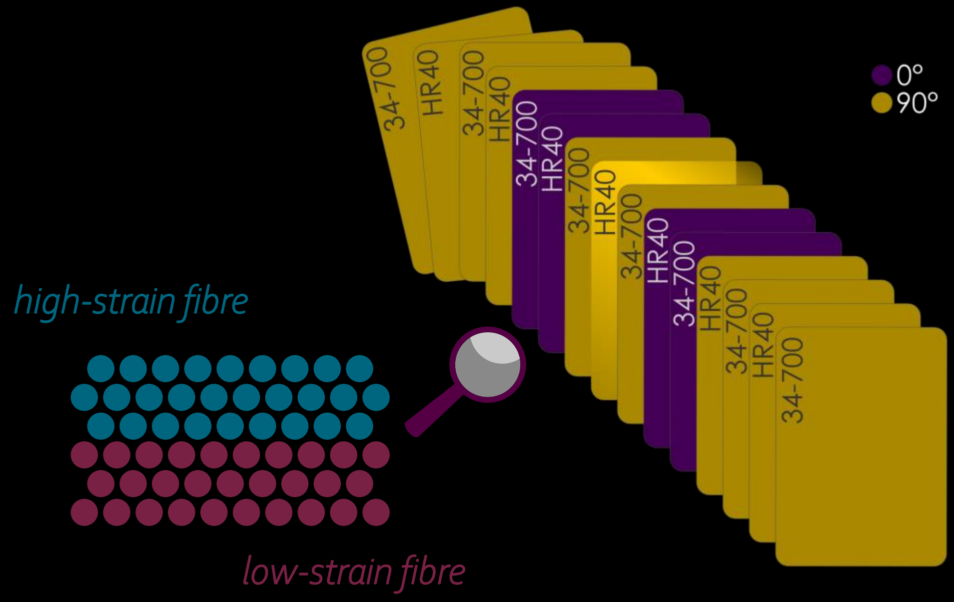


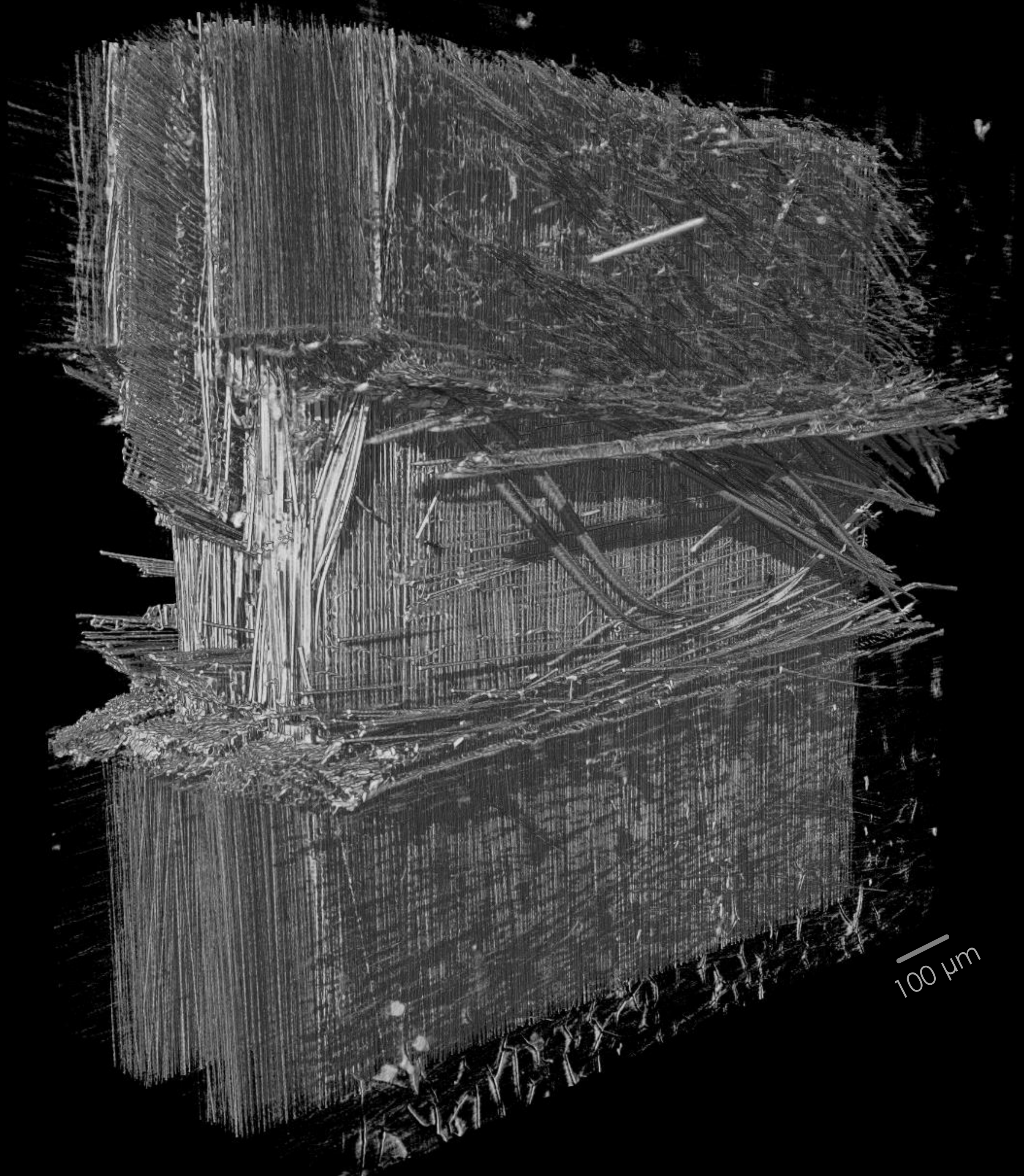
Fibre Breaks Ahead of the Crack Tip



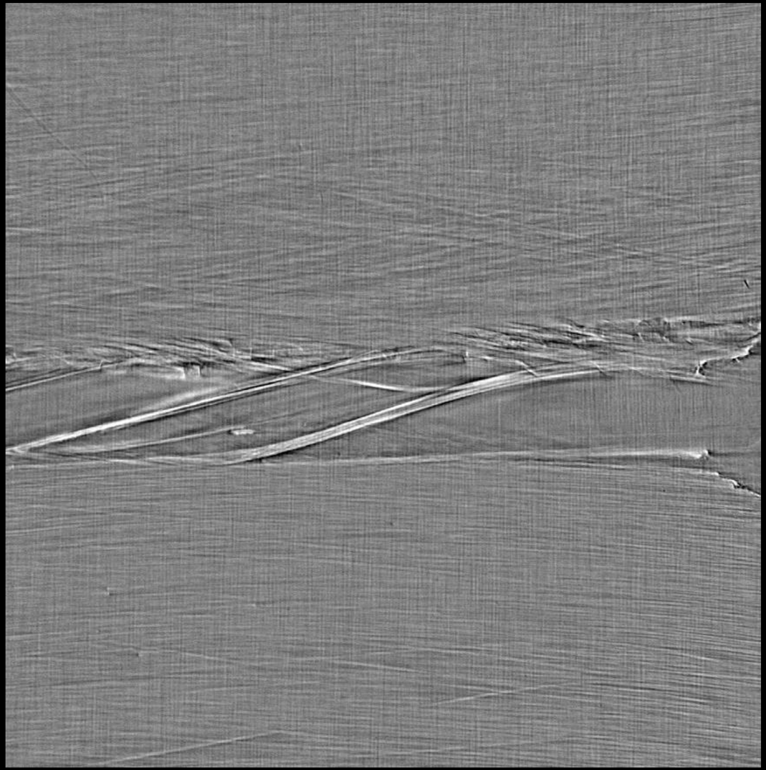
Ply-by-Ply Hybrid



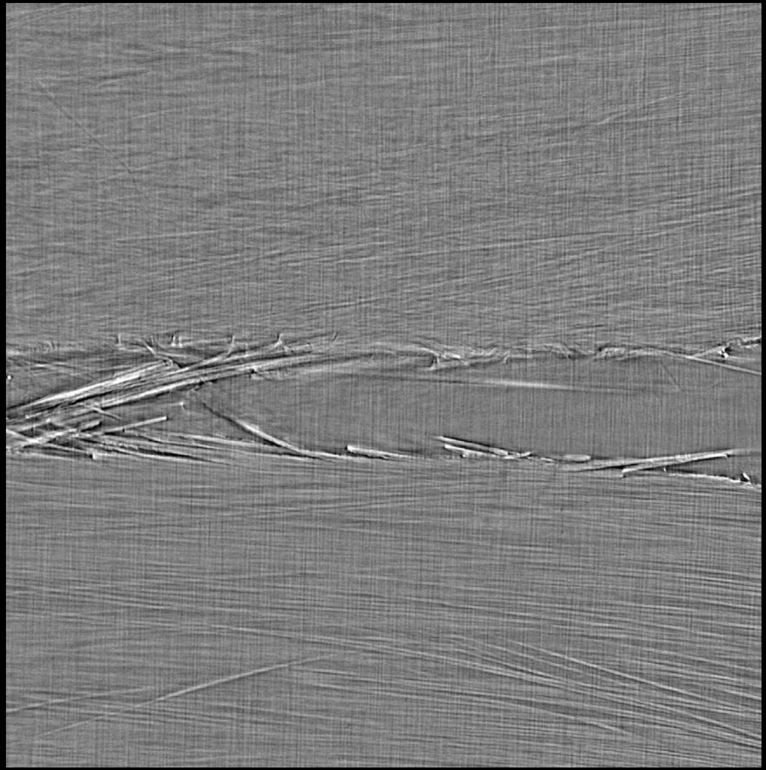




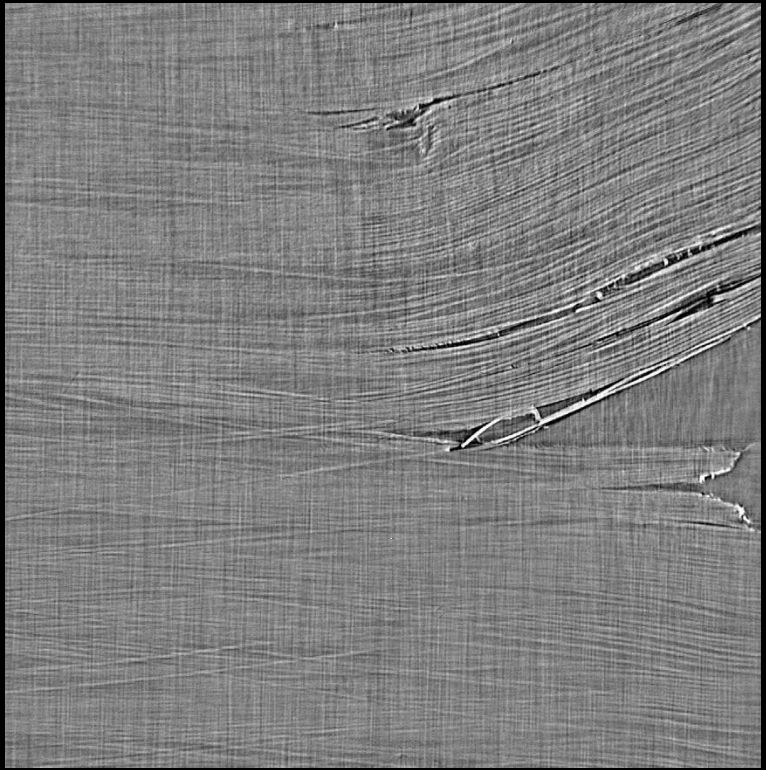
Ply-by-Ply Hybrid



First 90° Ply Block

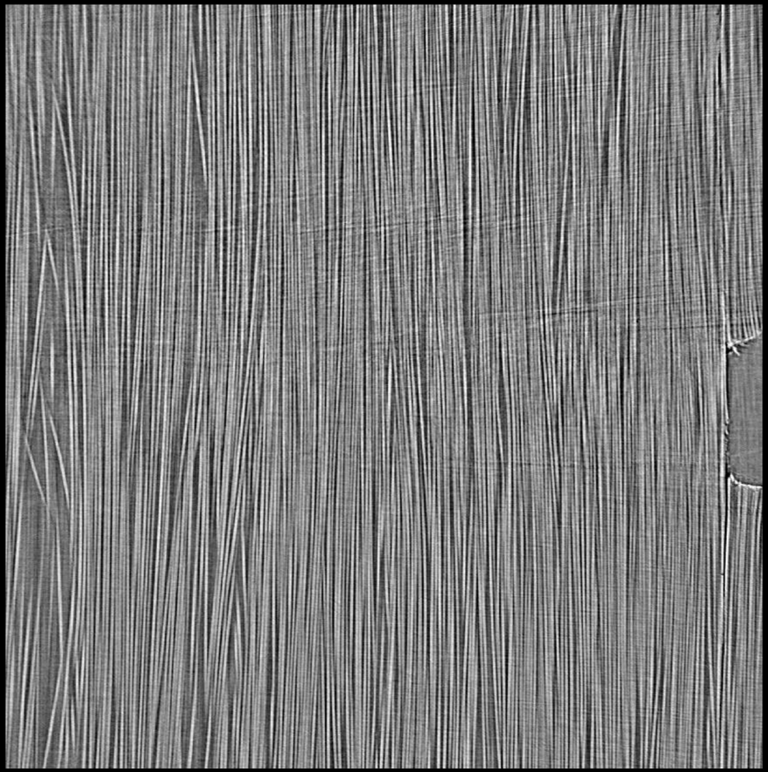


Second 90° Ply Block

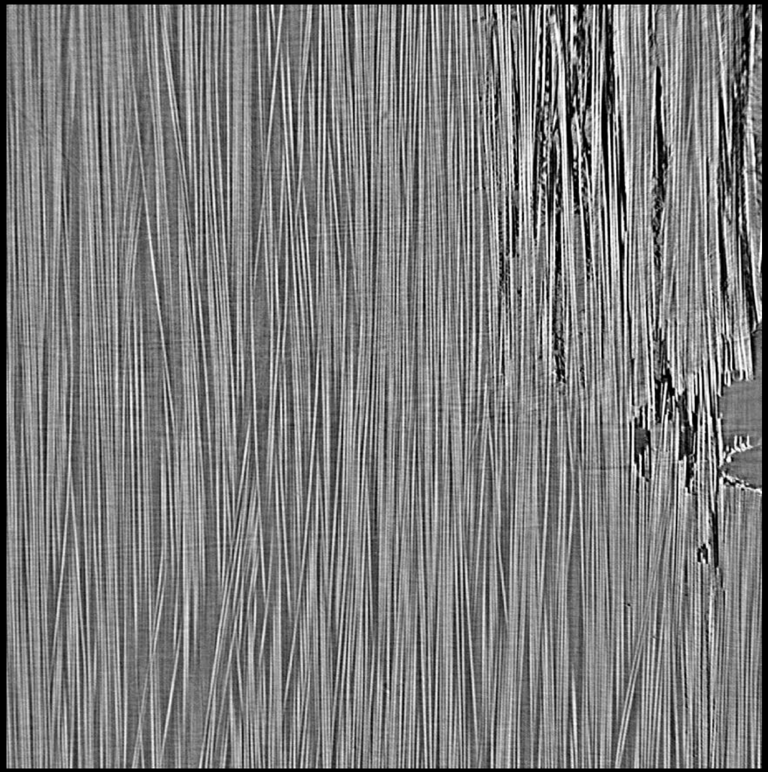


Third 90° Ply Block

Ply-by-Ply Hybrid

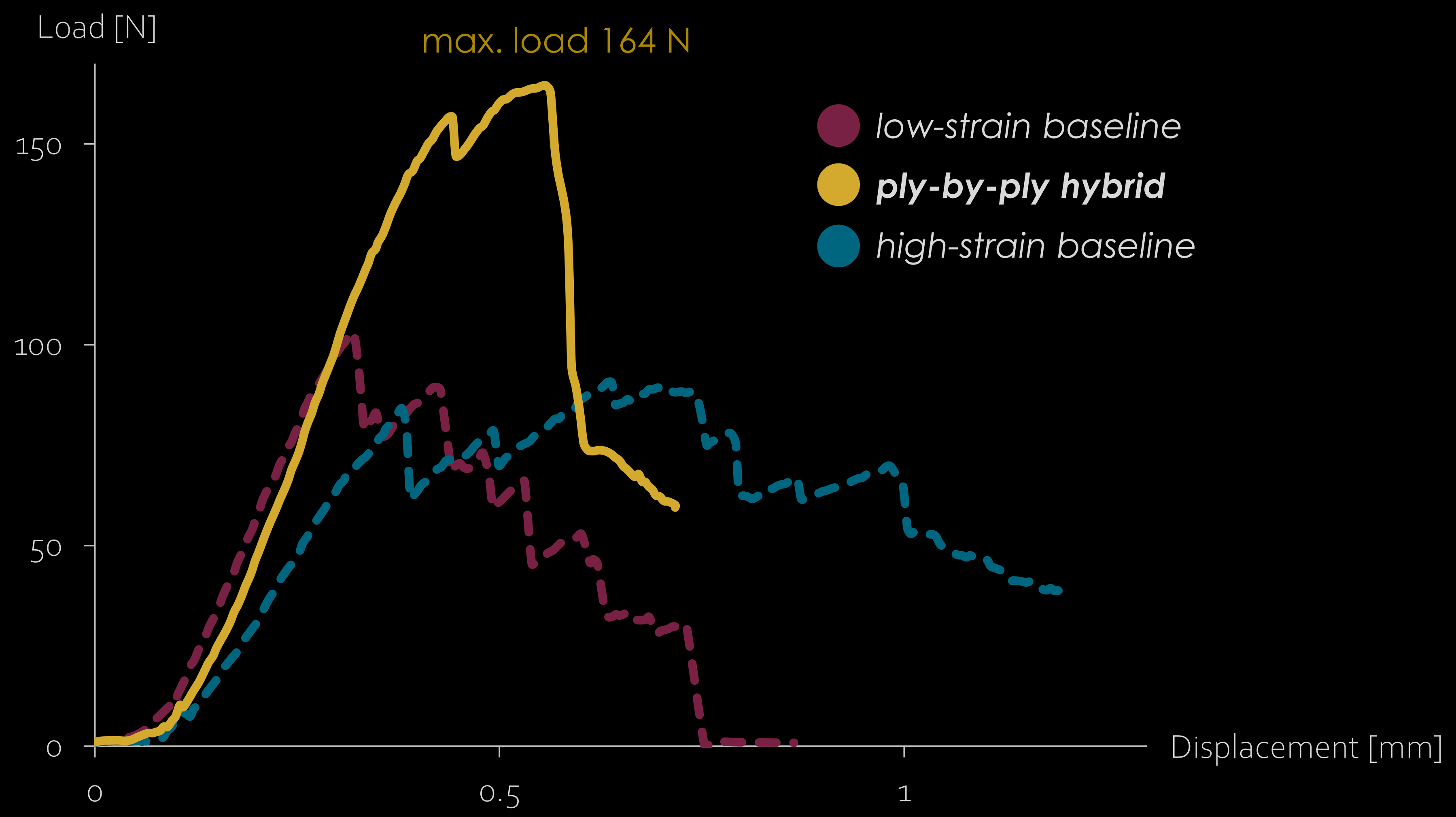


First 0° Ply Block

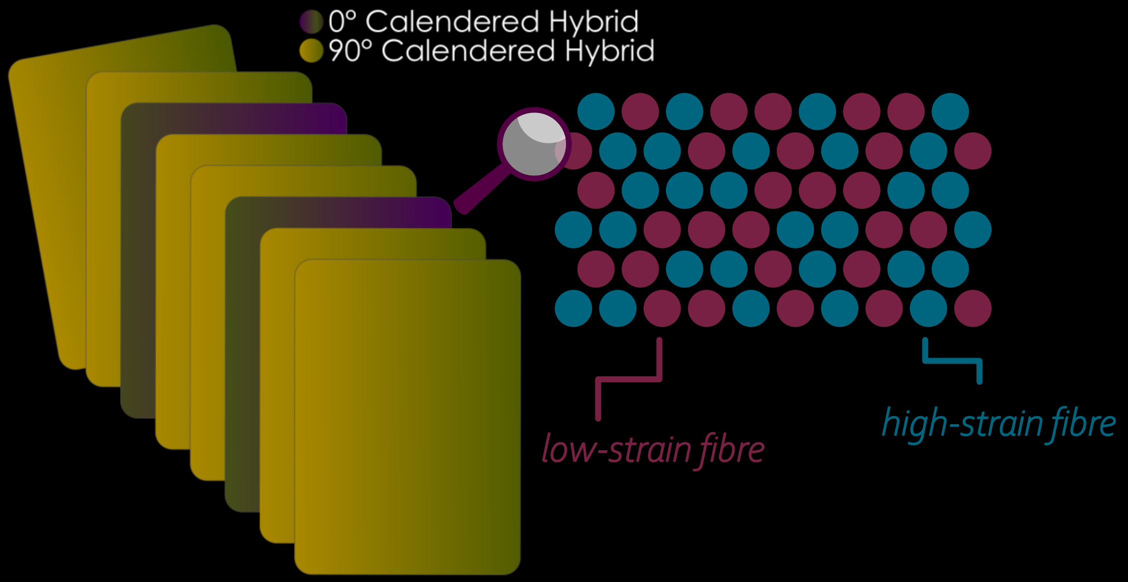


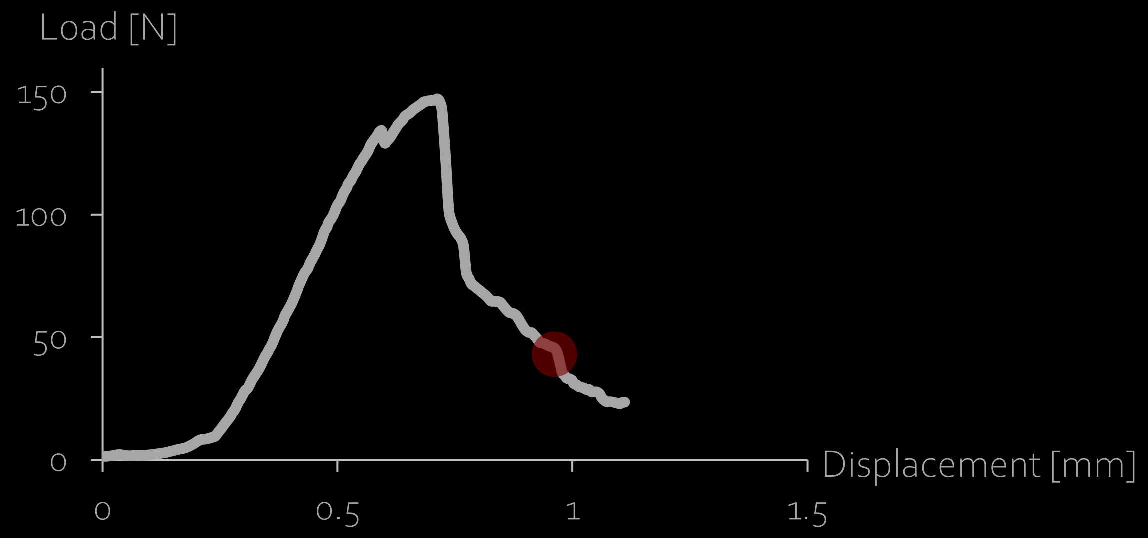
Second 0° Ply Block

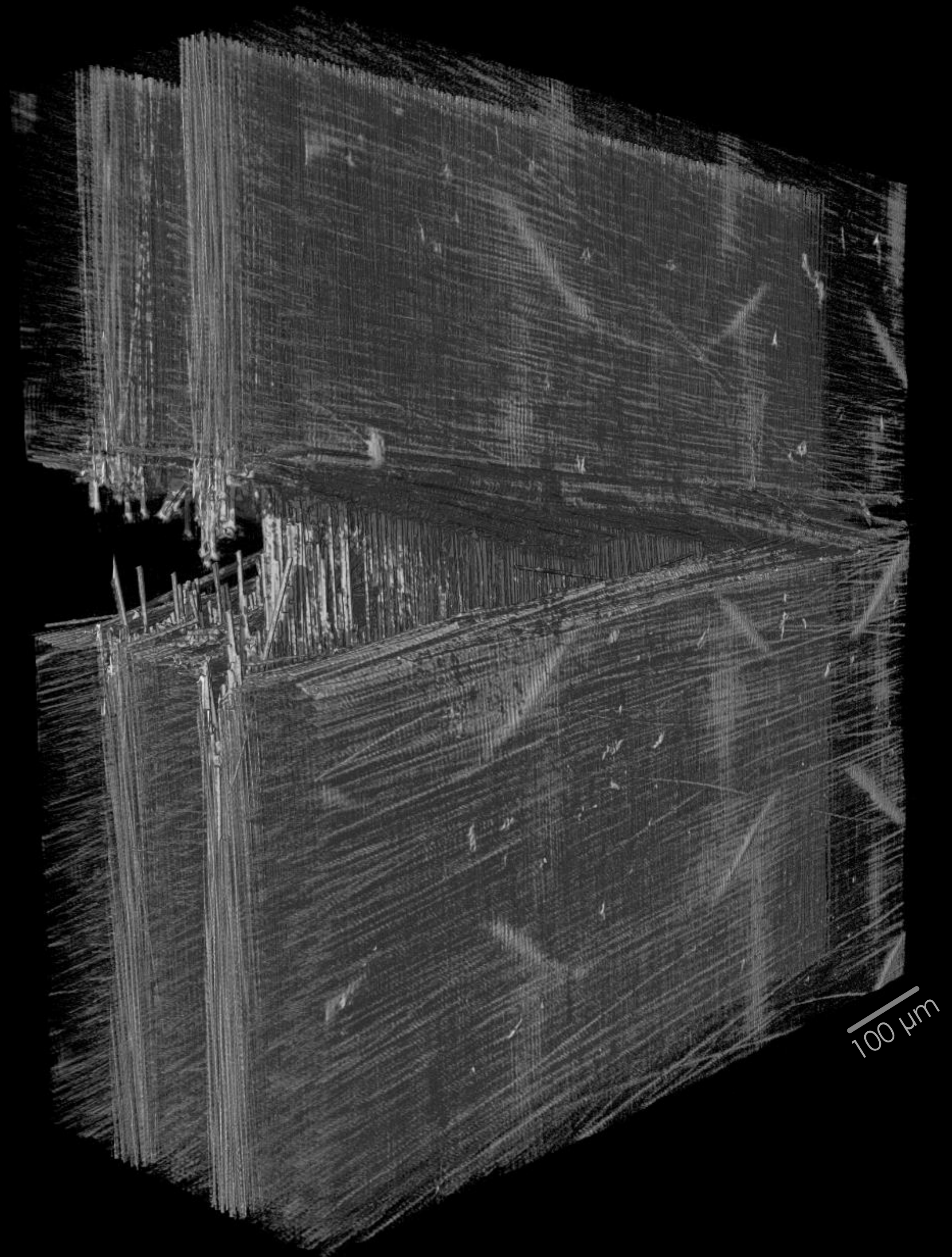
Ply-by-Ply Hybrid



Fibre-by-Fibre Hybrid



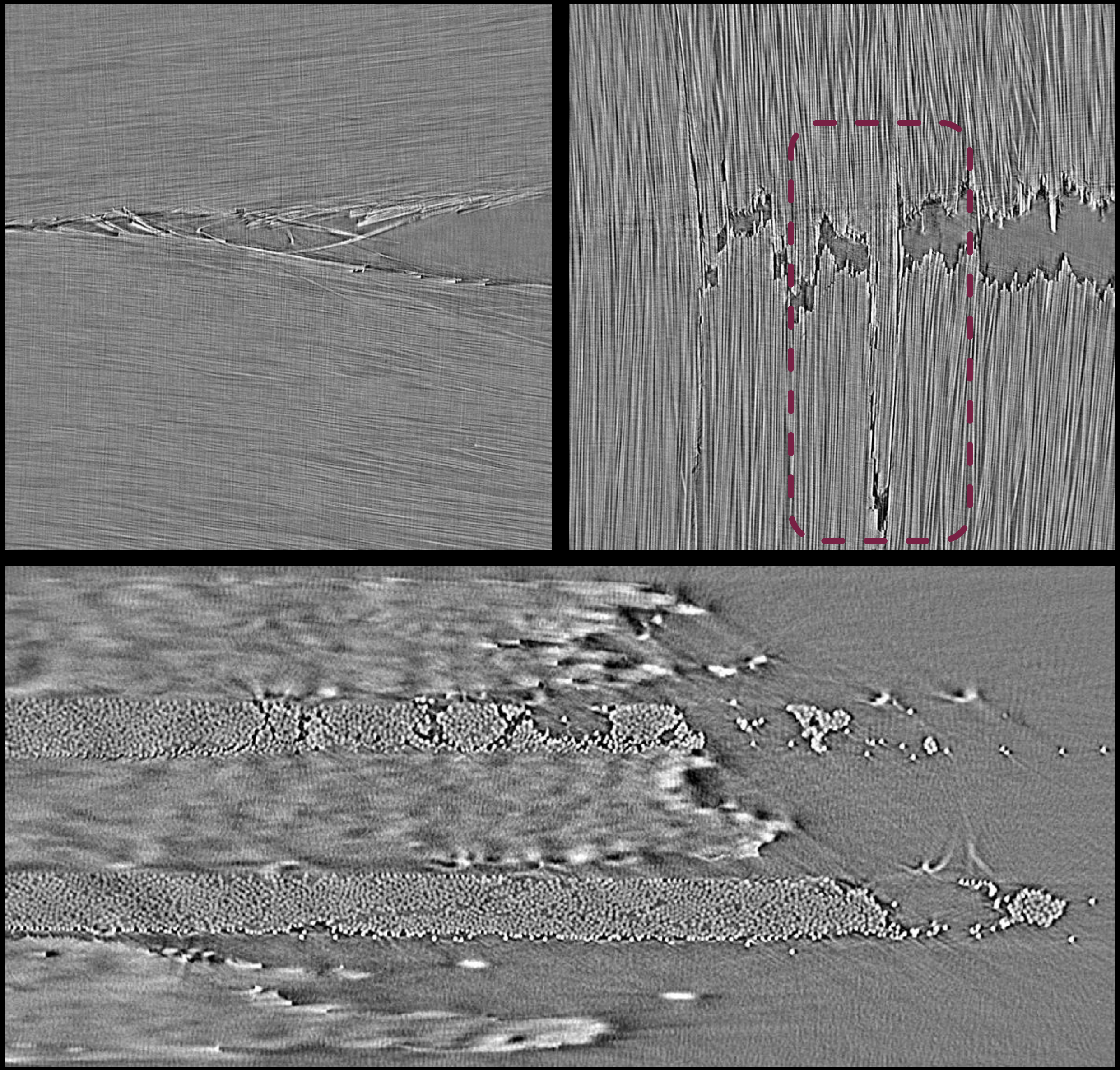




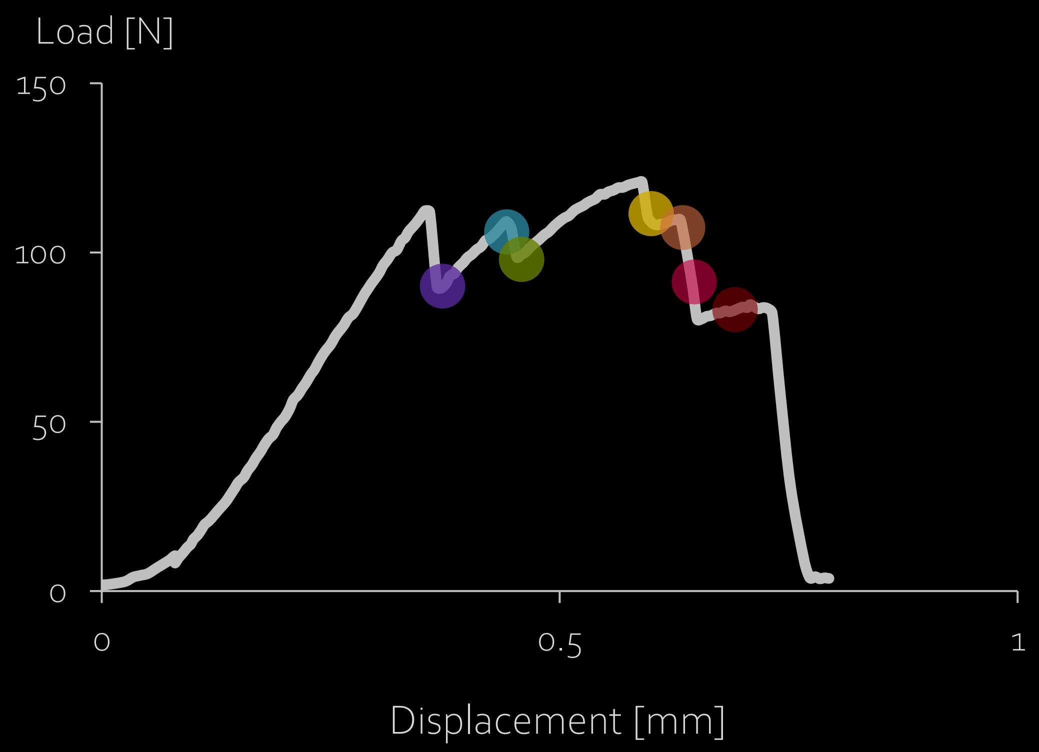
Fibre-by-Fibre Hybrid

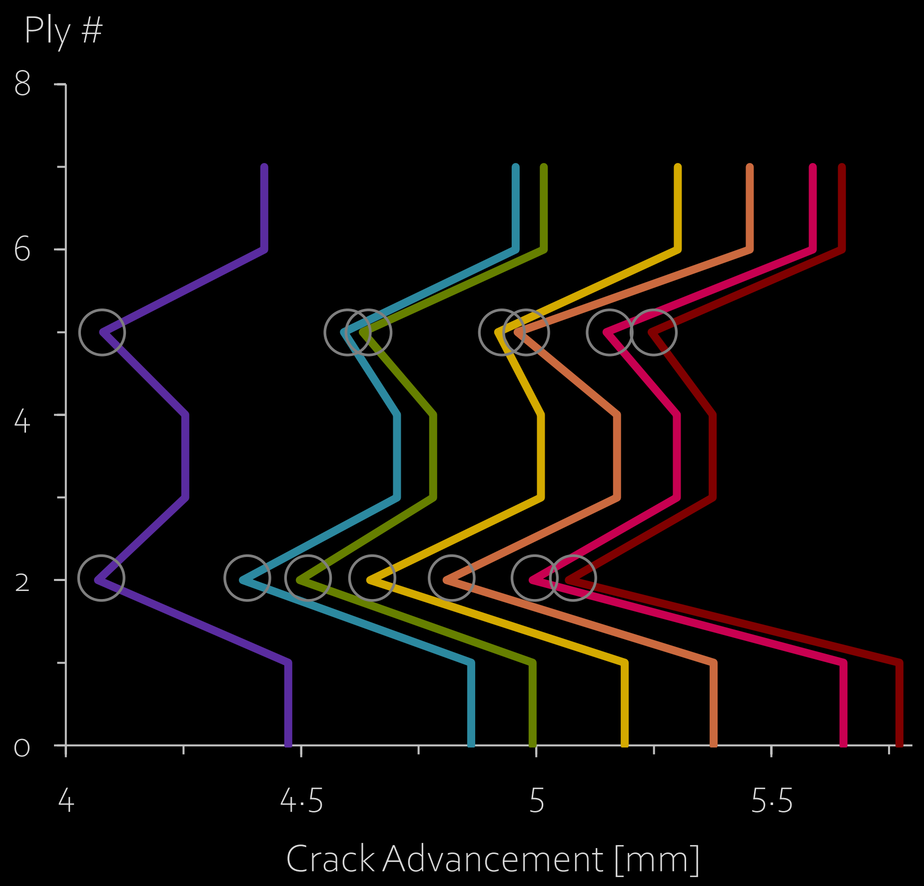
Significant bundle pull-out

Also noted in a high-strain baseline specimen



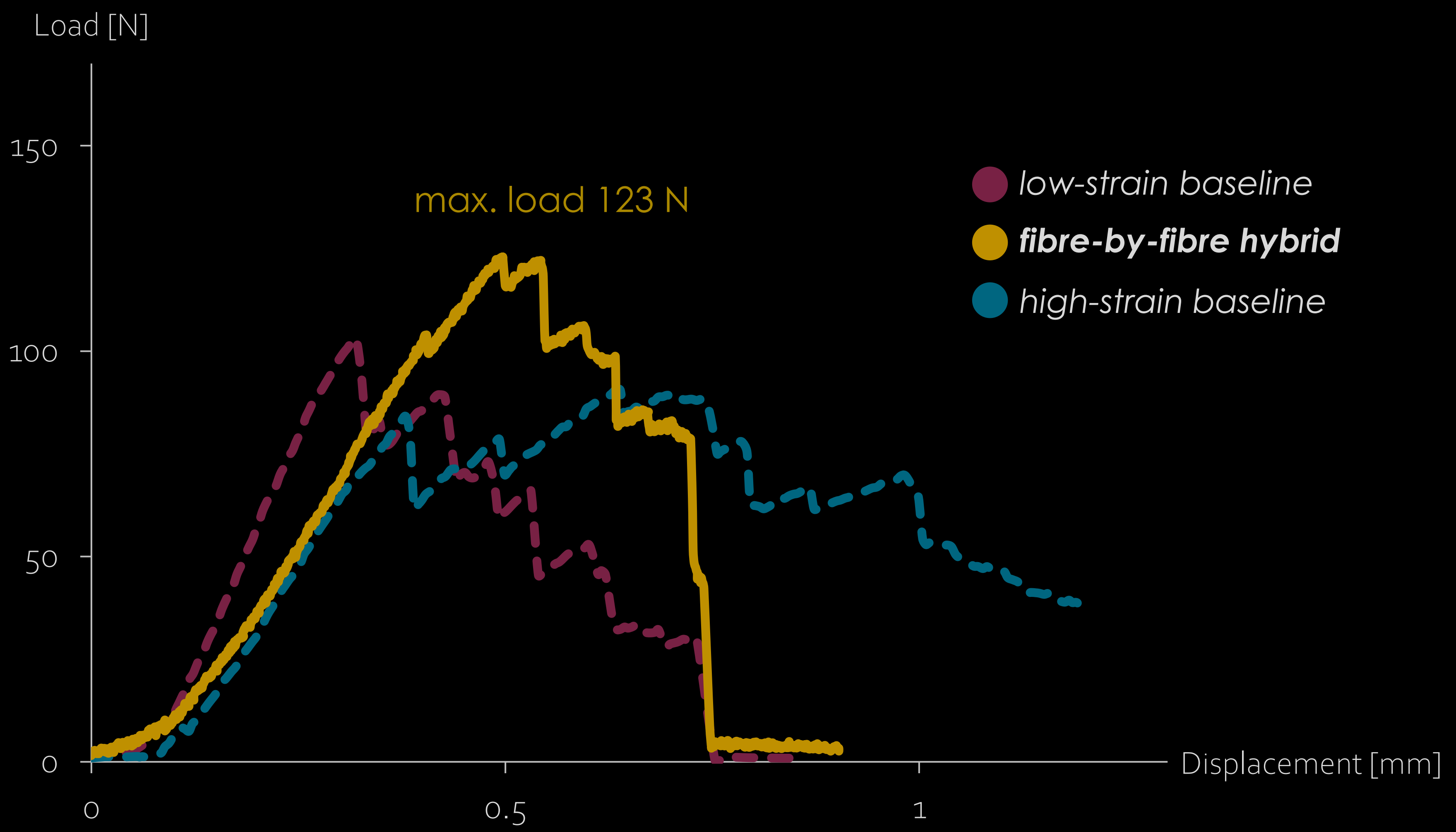
Fibre-by-Fibre Hybrid





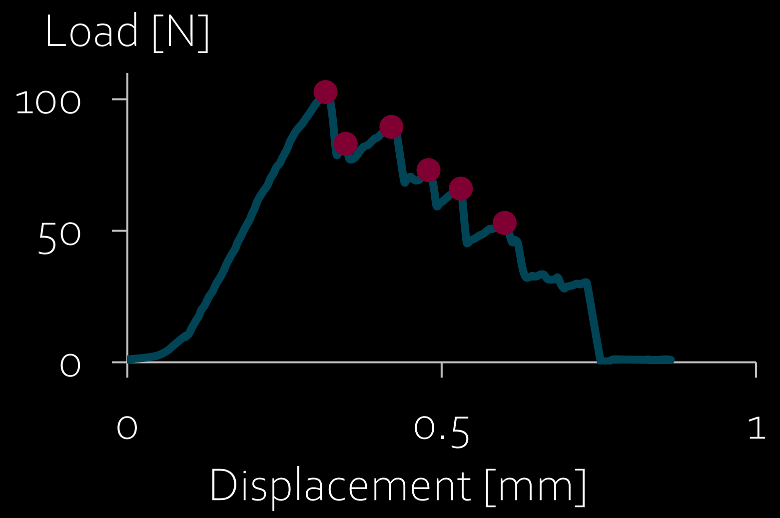
The difference between the crack fronts at 0° and 90° is 595±96 μm

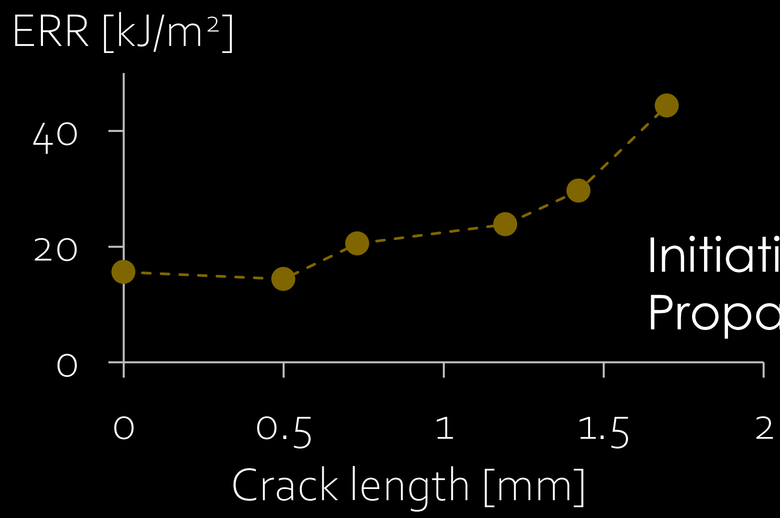
Fibre-by-Fibre Hybrid



R-Curves: Fracture Toughness Values

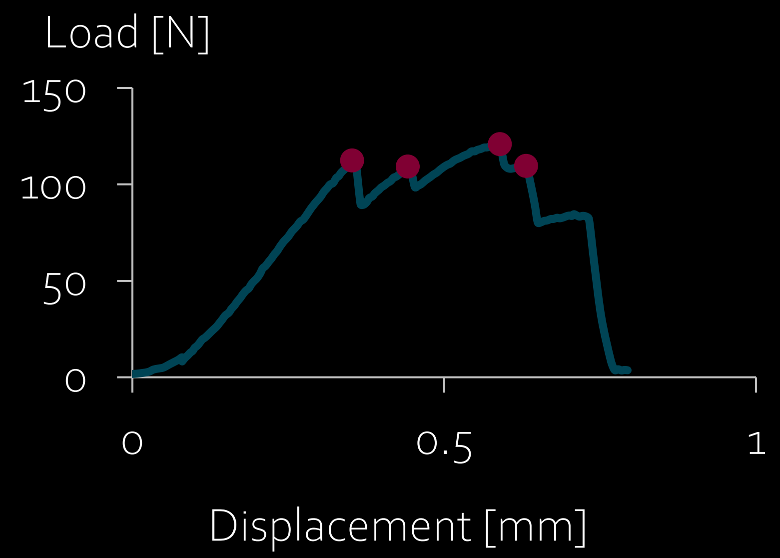
low-strain baseline

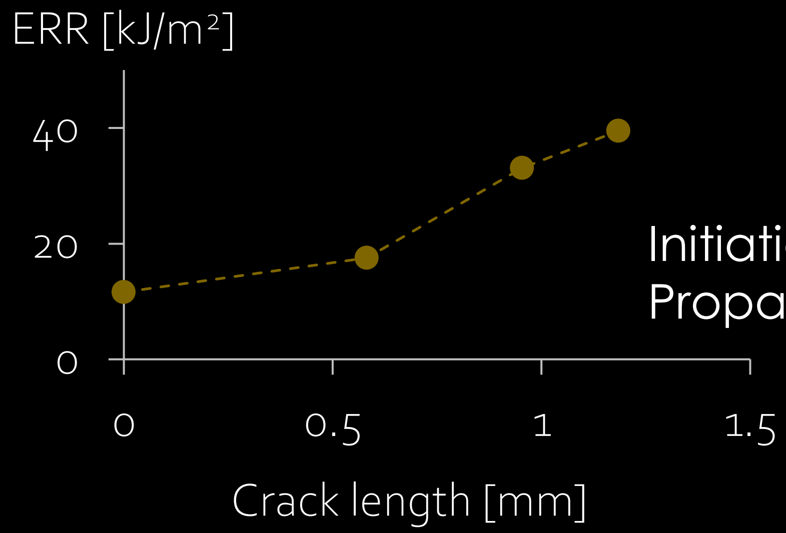




Initiation: 52.1 kJ/m^2
Propagation: 147.3 kJ/m^2

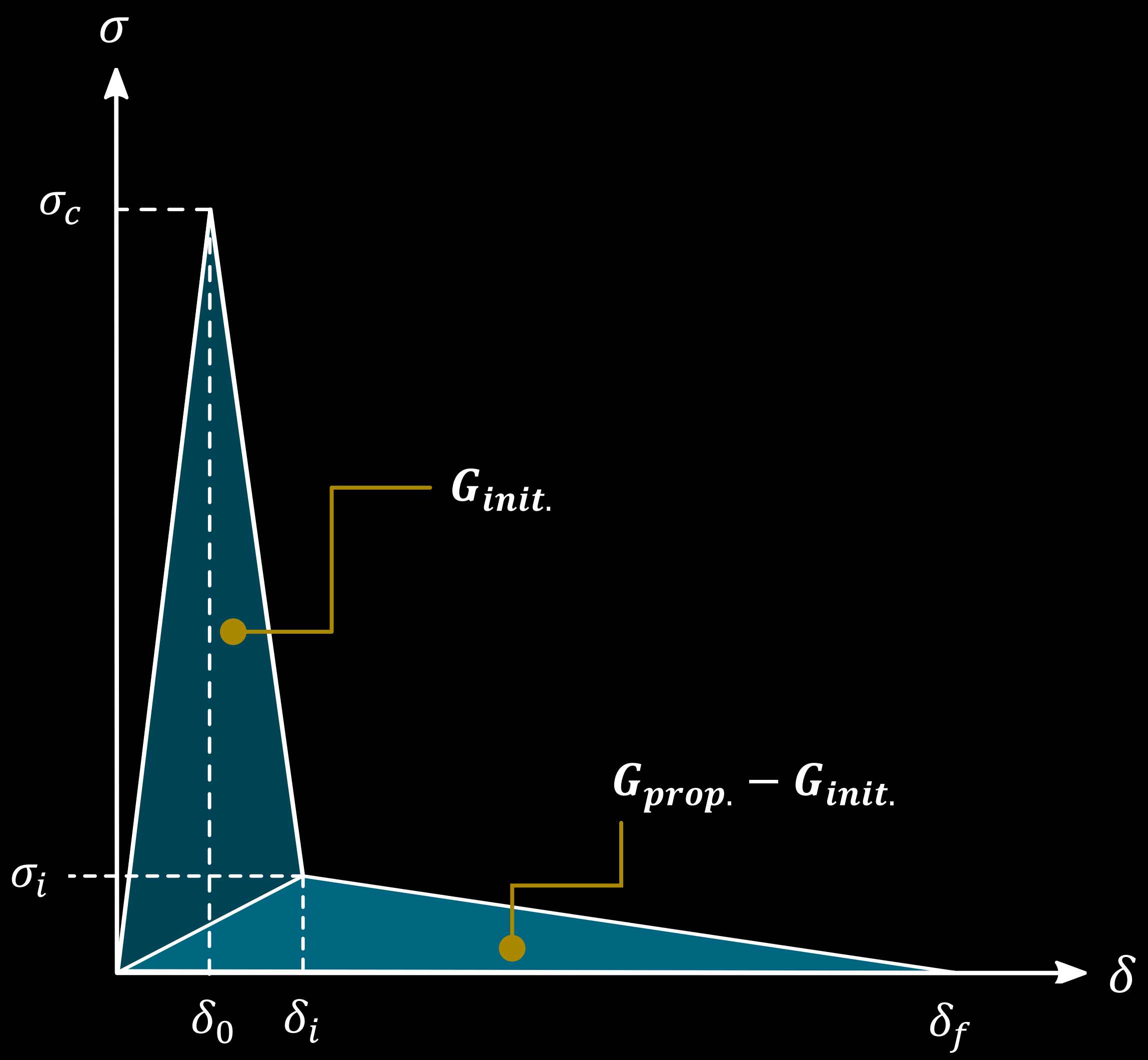
fibre-by-fibre hybrid



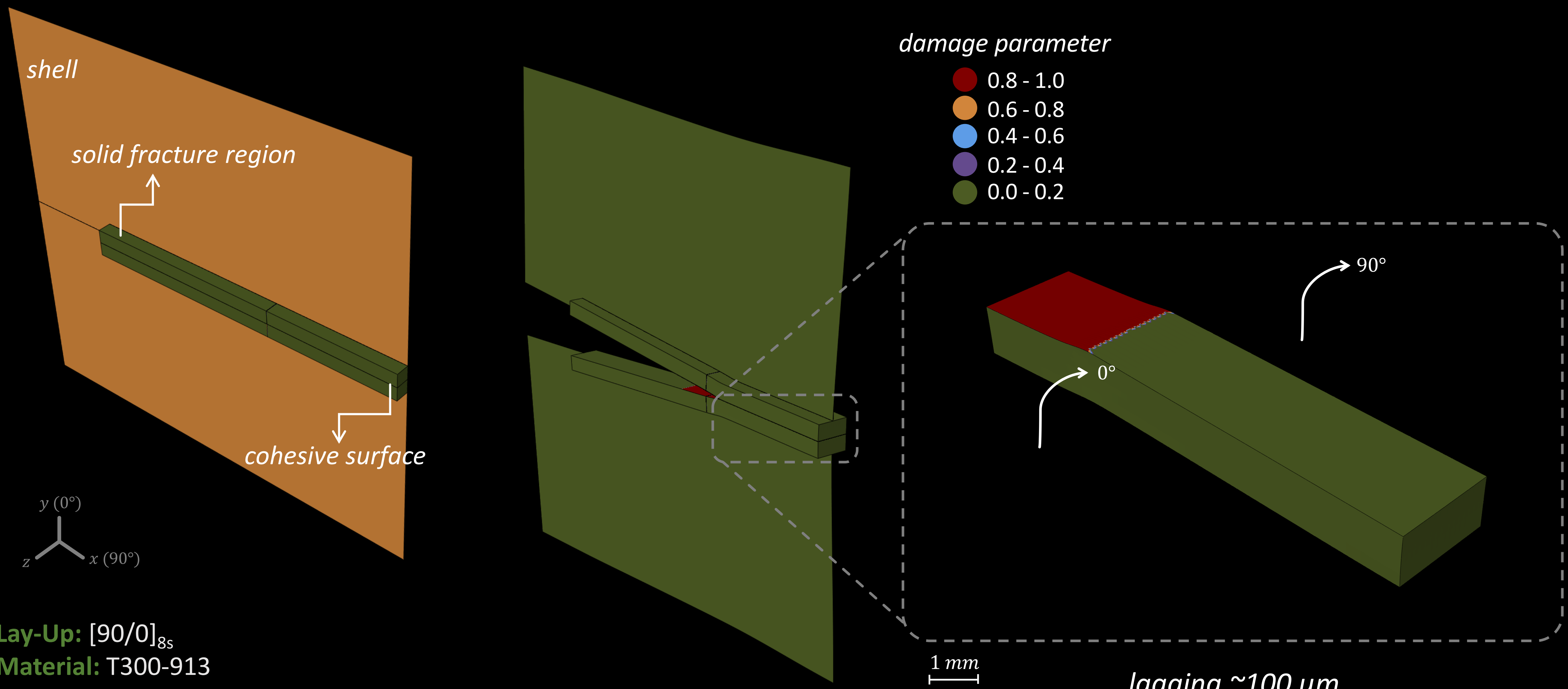


Initiation: **53.2** kJ/m^2
Propagation: **179.5** kJ/m^2

FE Model: Defining Fracture Behaviour



FE Model: Defining Fracture Behaviour



lagging ~100 μm

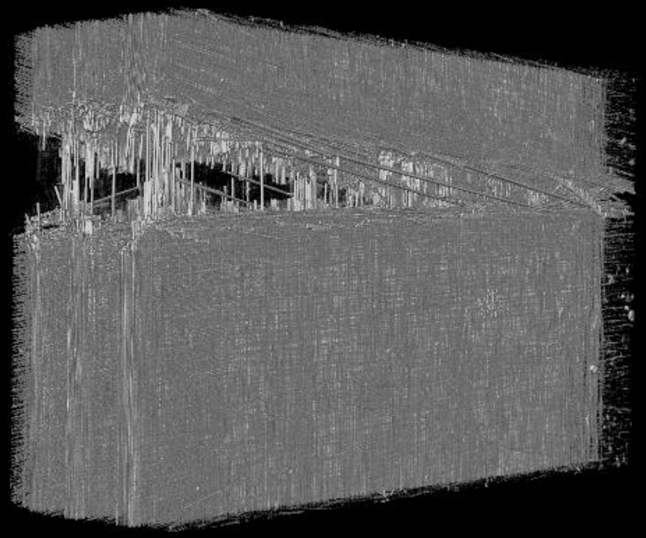
Lay-Up: $[90/0]_{8s}$
Material: T300-913

Conclusions

Results:

- The mini-protruded design, with a pre-crack half its length, results in stable crack propagation,
- 2D slices reveal advancing crack fronts in the 90° plies and lagging fronts in the 0° plies on fracture surface,
- FEM can capture this!
- Interlayer & intrayarn hybrids have a higher translaminar fracture toughness than either of their two baseline configurations.

Translaminar Fracture Analysis in Hybrid Fibre-Reinforced Composites through 4D in-situ Synchrotron Tomography



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MARIE CURIE ACTIONS

Composite materials group

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