# Simulating fracture and fatigue

Prof. Dr. Laura De Lorenzis

D-MAVT, IMES, Computational Mechanics

Computational tools for fracture simulation
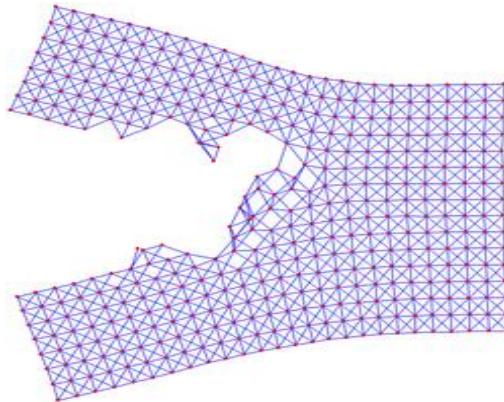

Remeshing
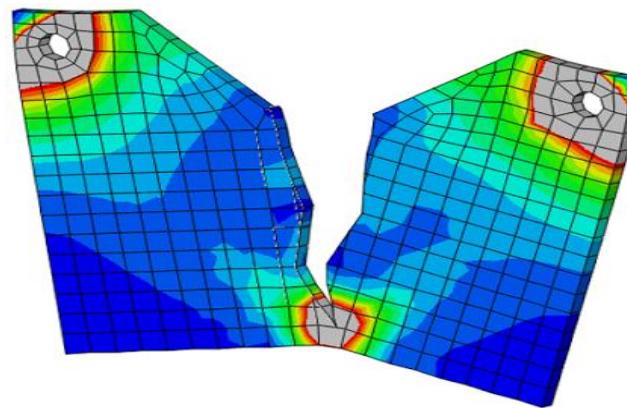
GFEM, XFEM
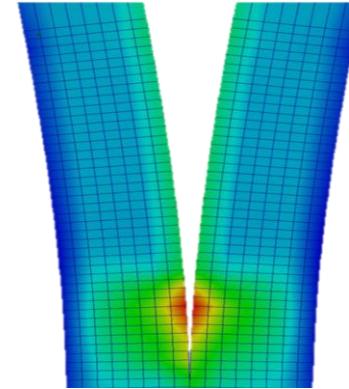
Cohesive zone modeling

Damage

$d = 1$

$\text{supp}\,(d) \sim l$

$d = 0$
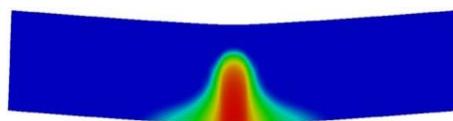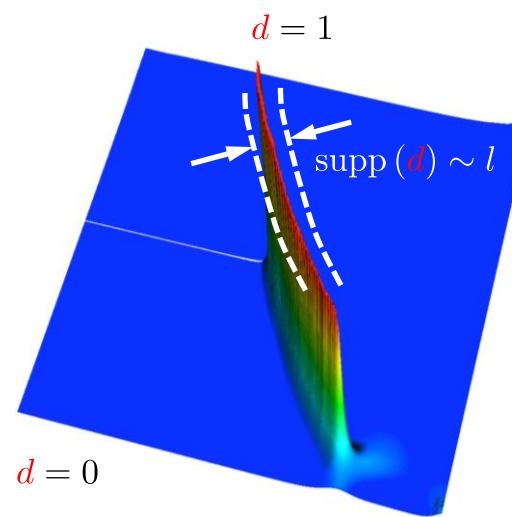
Phase-field modeling

Advantages:
- no need for ad-hoc criteria (initiation, propagation, merging, branching)
- fixed mesh
- 3D

Example 1: „blind" simulation of brittle fracture

Multiaxial experiments
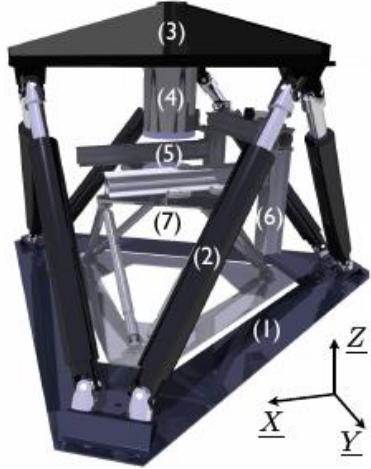
- Multiaxial electromechanical testing machine (hexapod)
- Full-field displacement from DIC
- interactive adjustment of boundary conditions (*multiple input-multiple output integrated DIC* algorithm)

Input parameters
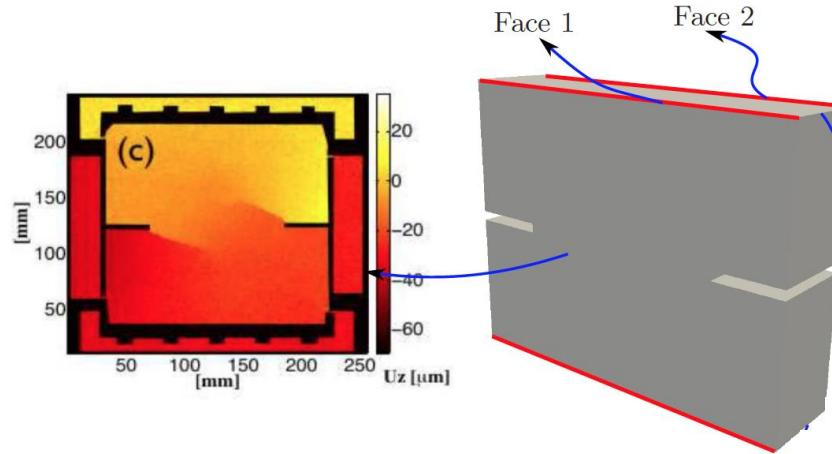
| Property	Values	
E	18 (GPa)	✅
ν	0.2 (-)	
σ_c	3.9 (MPa)	✅
G_c	0.01 (N/mm)	calibration
ℓ	0.6241 (mm)	computation

Normal force
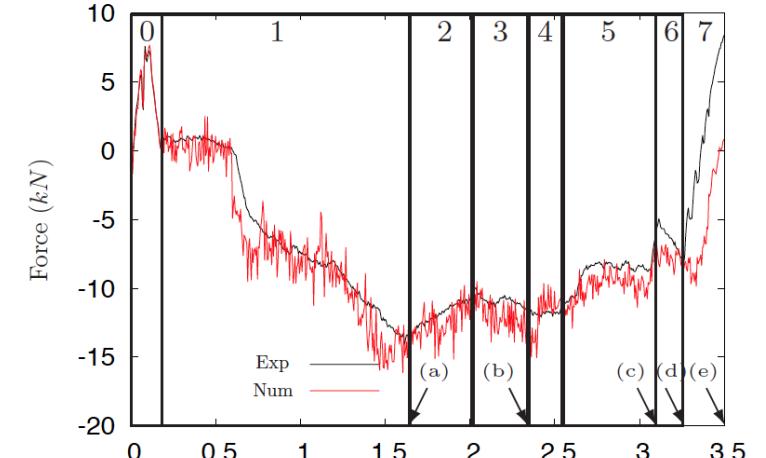
Shear force
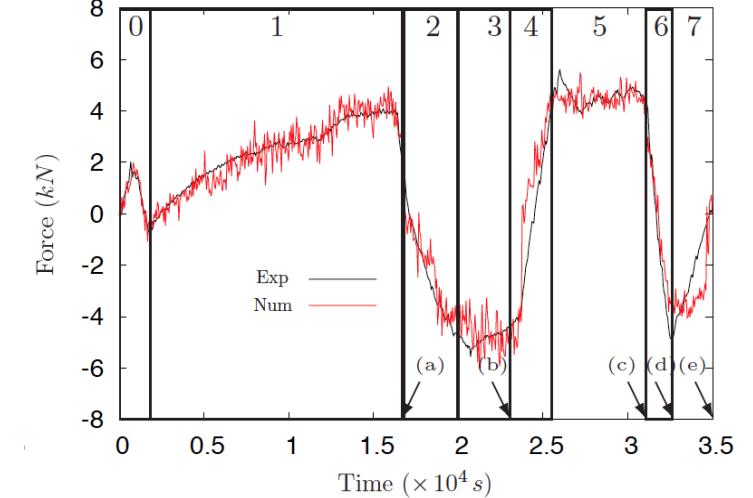
# Example 2: fracture of heterogeous materials with real geometry

**Computed tomography**
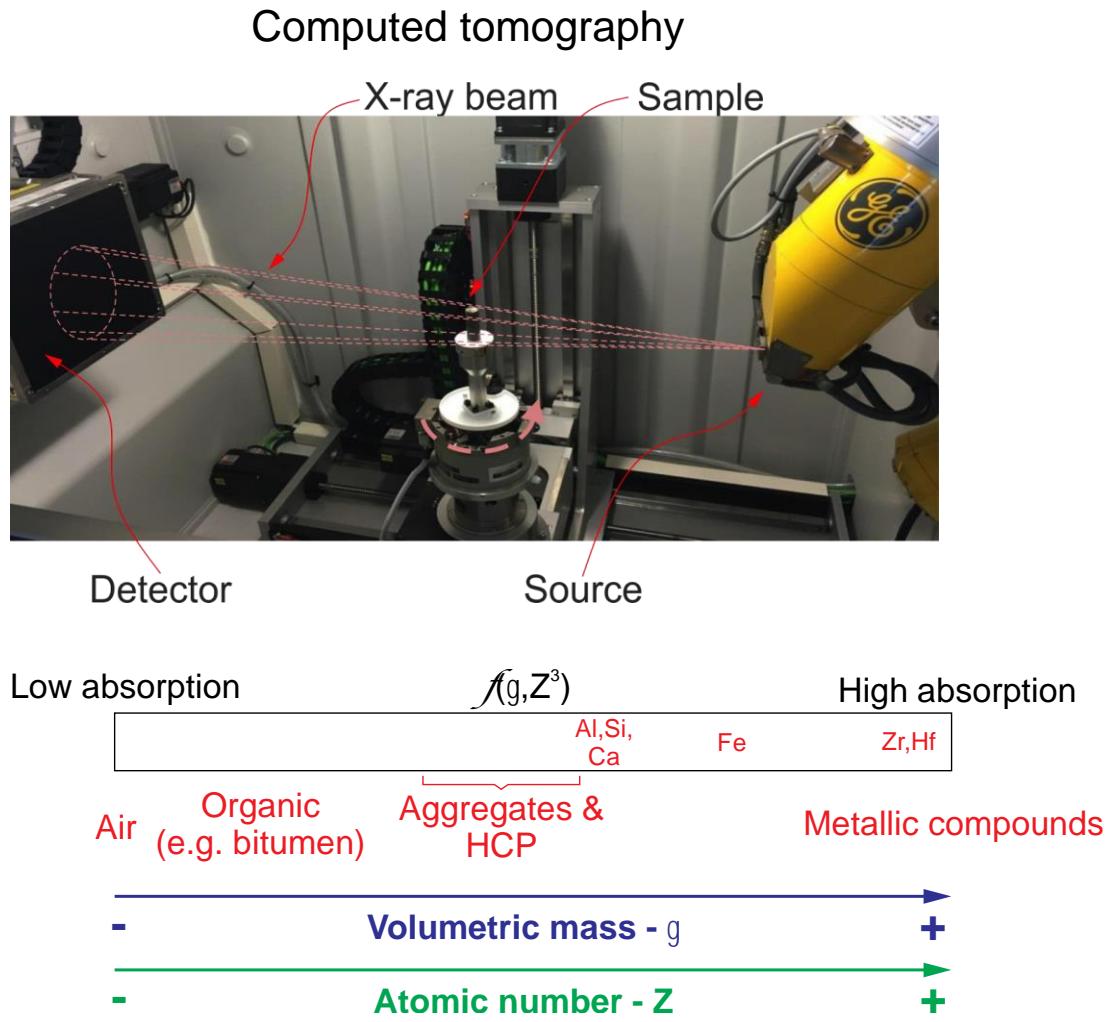

In-situ testing
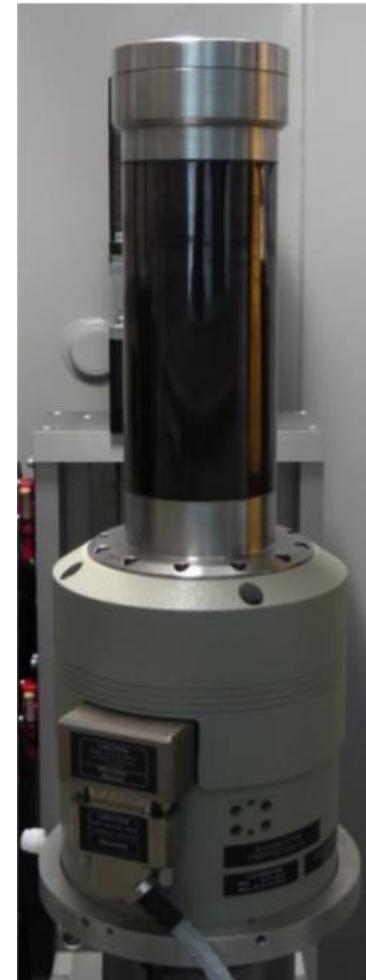
Contrast enhancement
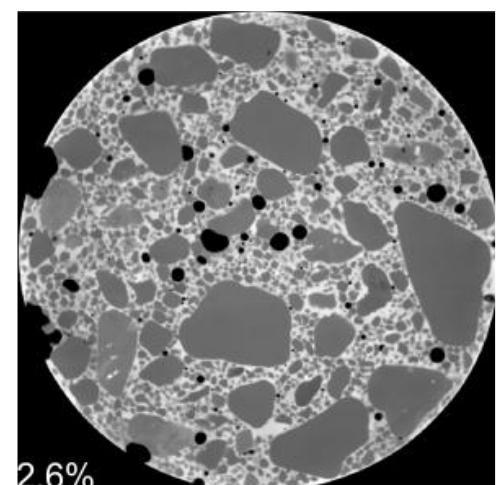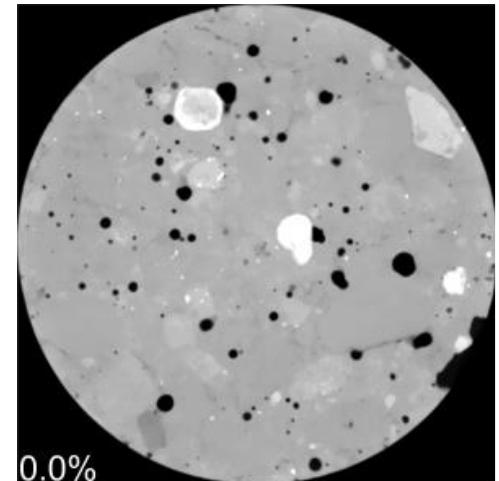
Example 2: fracture of heterogeous materials with real geometry

Computed tomography
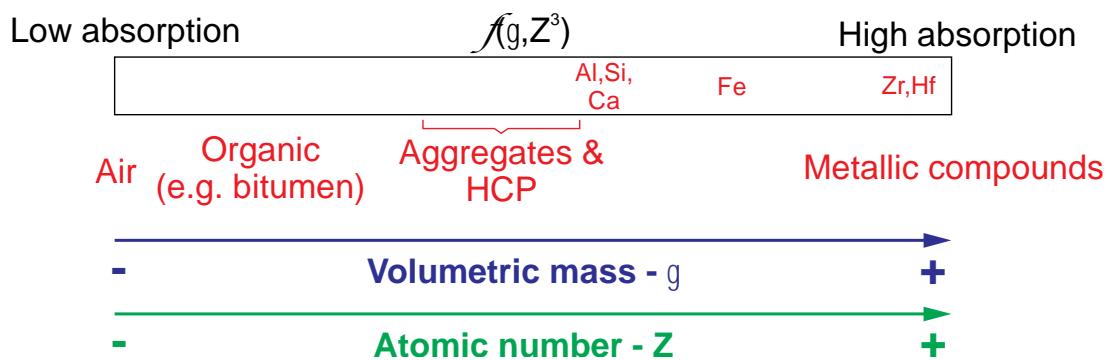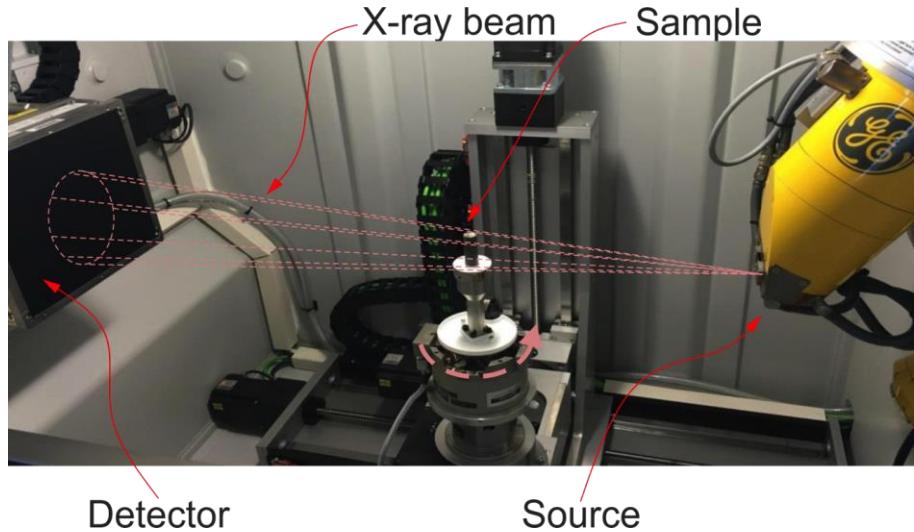
Phase-field simulations

X-ray beam   Sample

Detector   Source

Low absorption $f(g, Z^3)$ High absorption

| Al,Si, Ca | Fe | Zr,Hf |

Air   Organic (e.g. bitumen)   Aggregates & HCP   Metallic compounds

Volumetric mass - g
-    +

Atomic number - Z
-    +
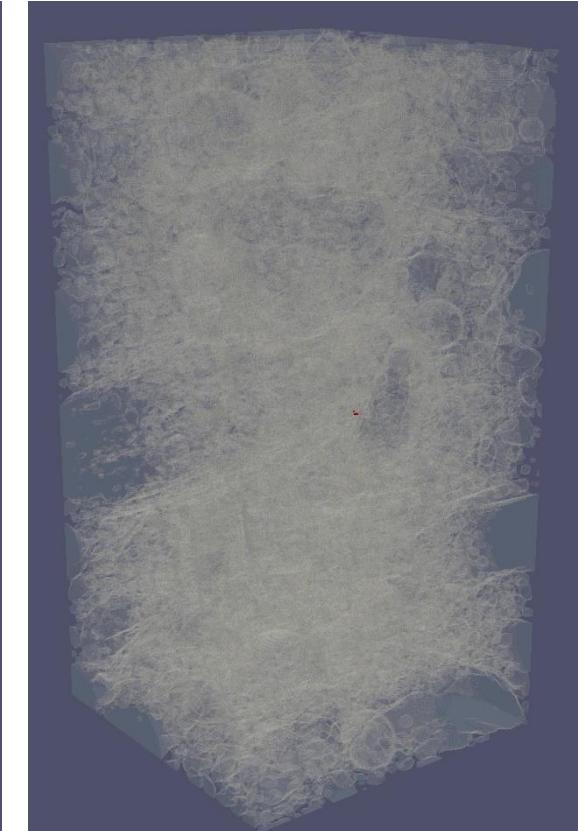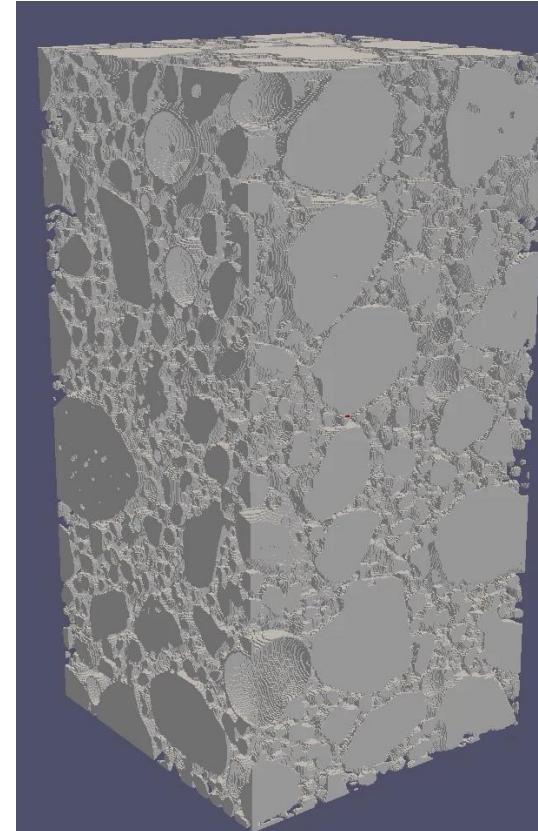
Example 3: desiccation cracking

Diffuse cracking at cake tip

1 cm
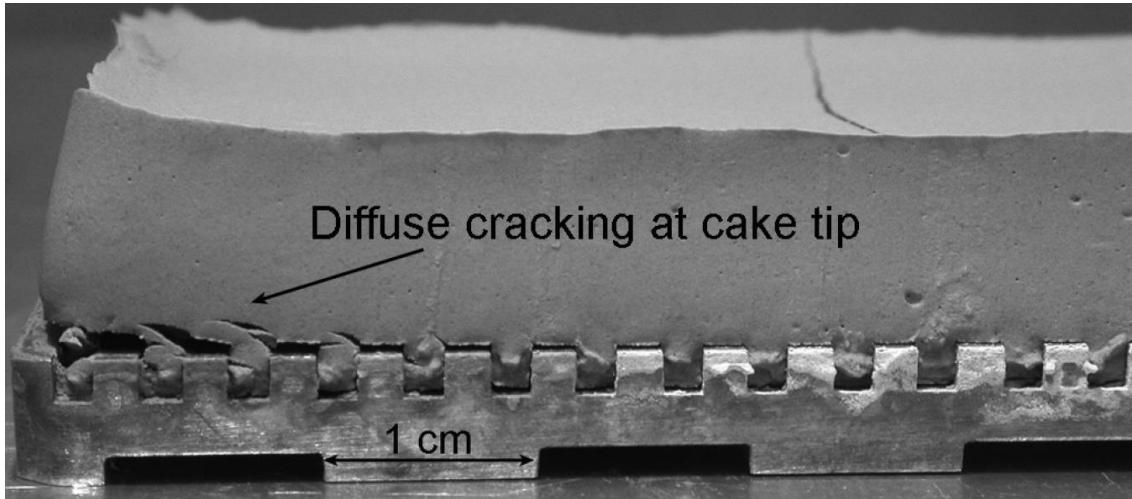
Experiments by Péron (2009) and Stirling (2014)

phase_field
0,000e+00   0,25   0,5   0,75   1,000e+00
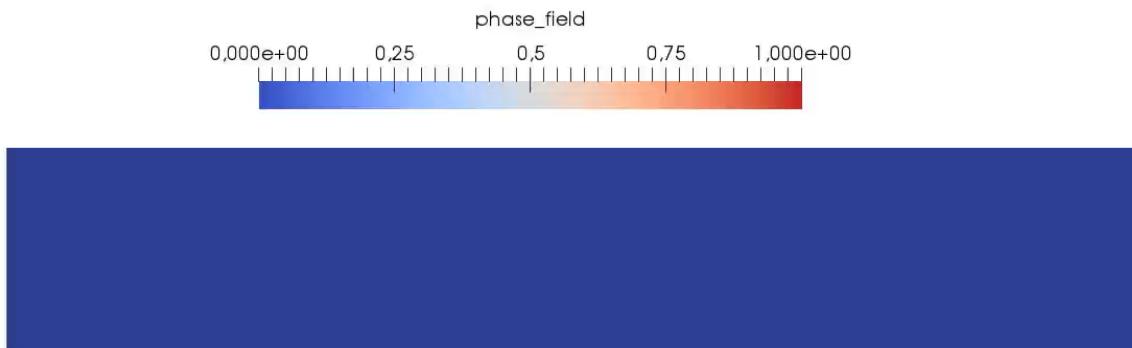
Cajuhi, Sanavia, LDL (2017)
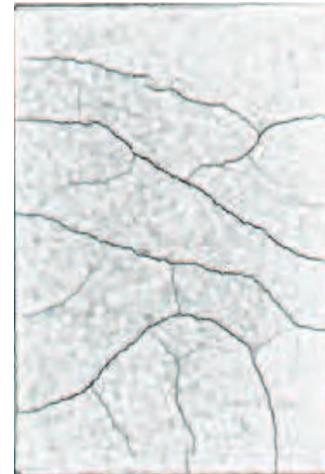
Experiments by
Lakshmikantha (2009)
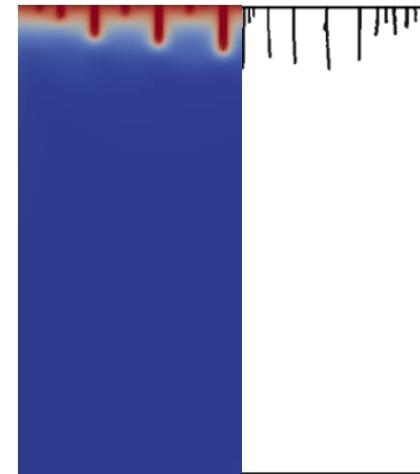
Experiments by
Bisschop et al. (2011)

phase_field
1,000e+00
0,75
0,5
0,25
0,000e+00

Example 4: fatigue

Wöhler curves

Paris curves
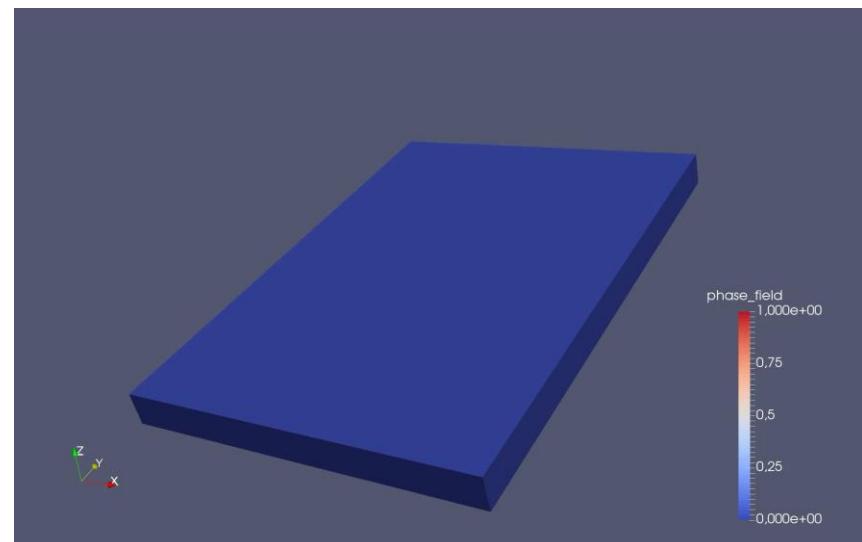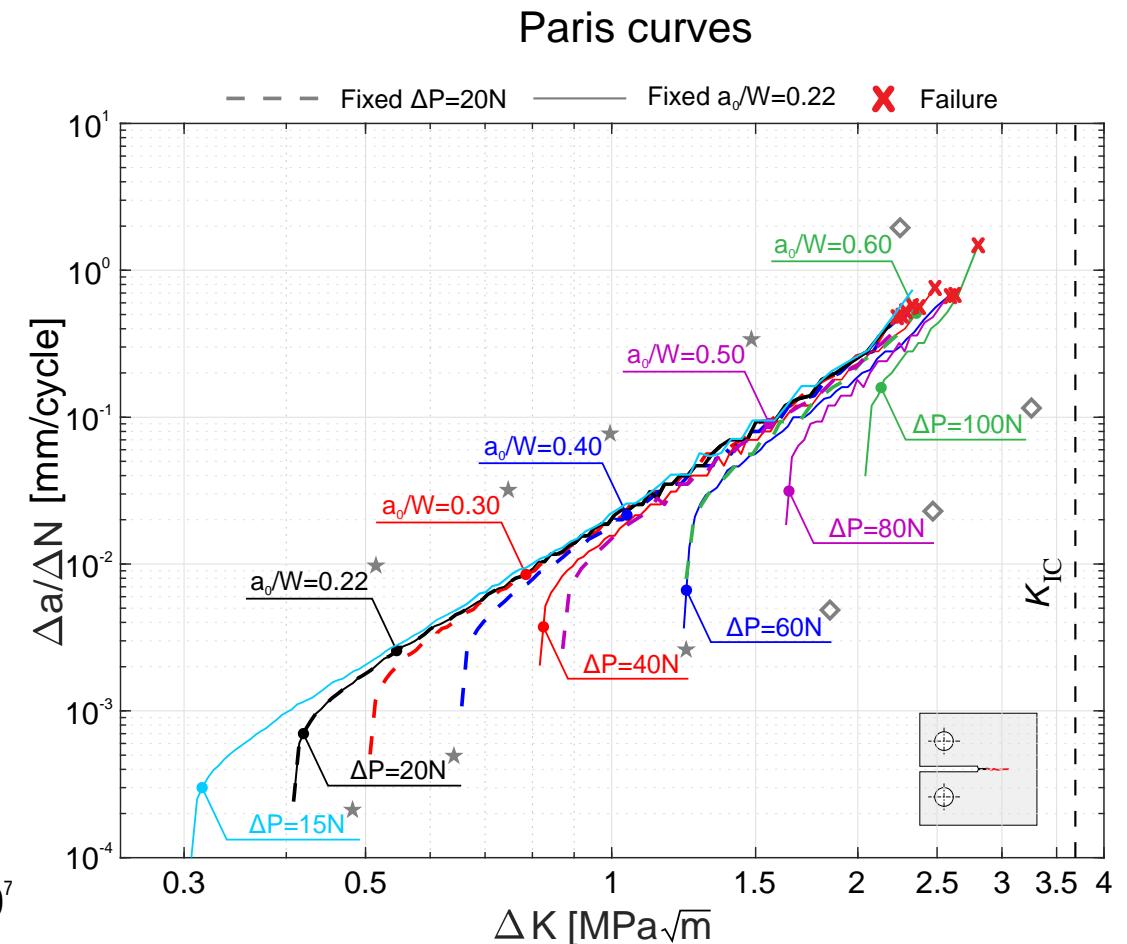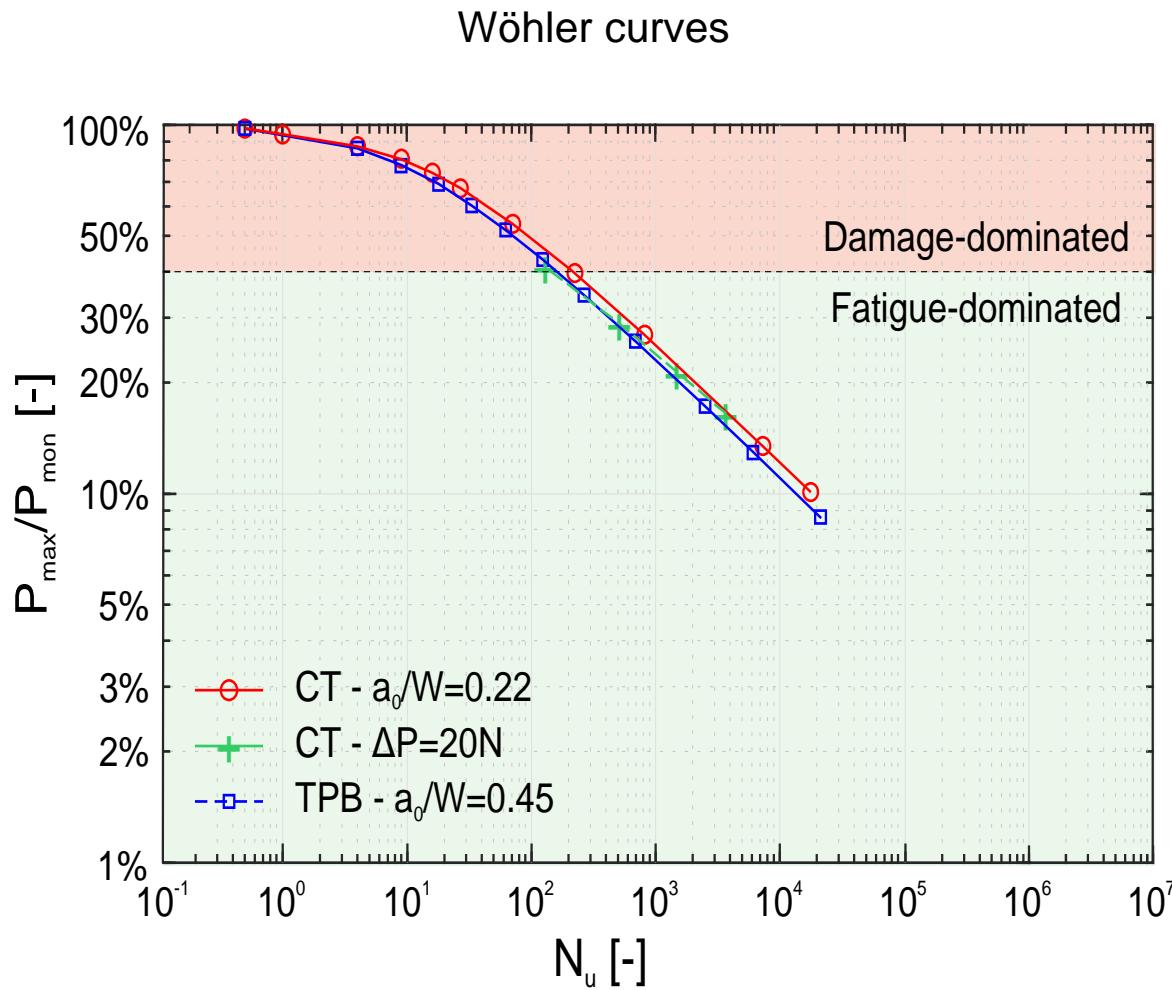
Example 4: fatigue
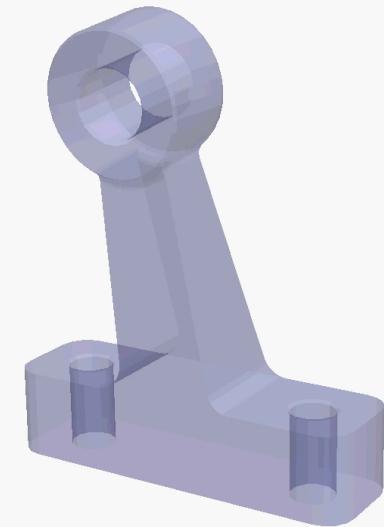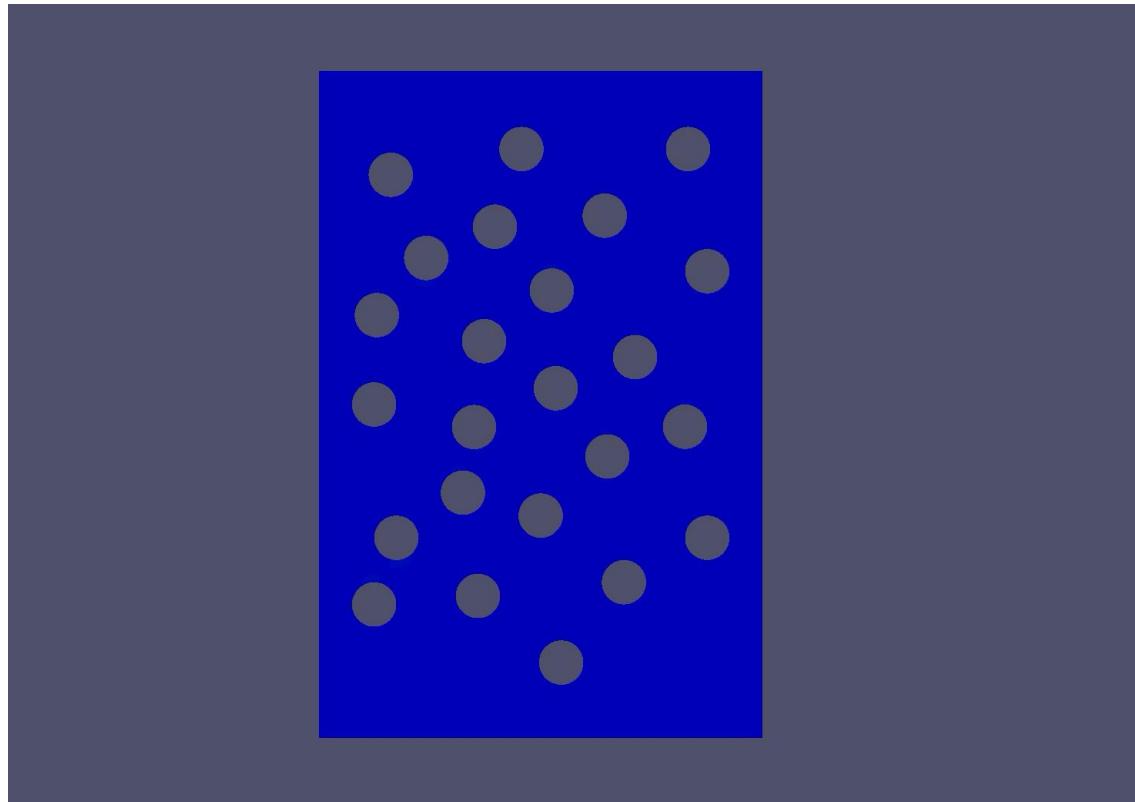
ETH zürich

Thank you for your attention!

Prof. Dr. Laura De Lorenzis
ldelorenzis@ethz.ch

ETH Zurich
D-MAVT
Tannenstr. 3
8092 Zürich, Switzerland

www.compmech.ethz.ch (coming soon!)