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Sattelfest und gut behütet – optimierte Lattice-Strukturen für Sicherheit und Komfort

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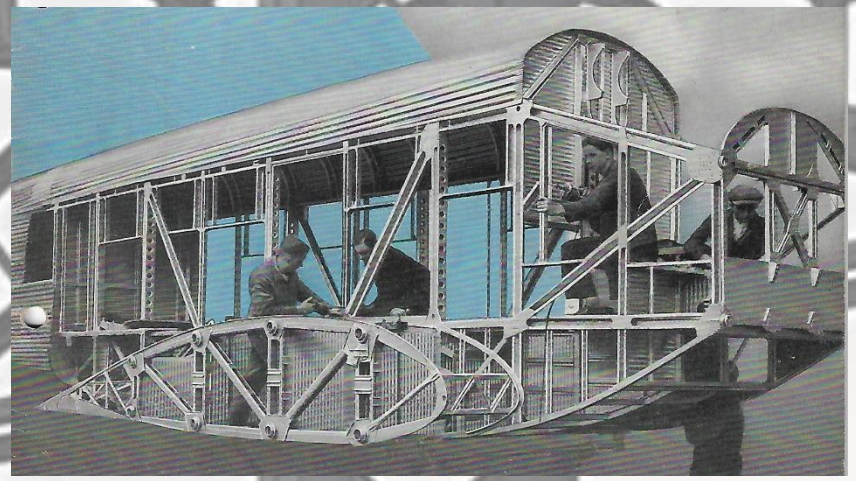
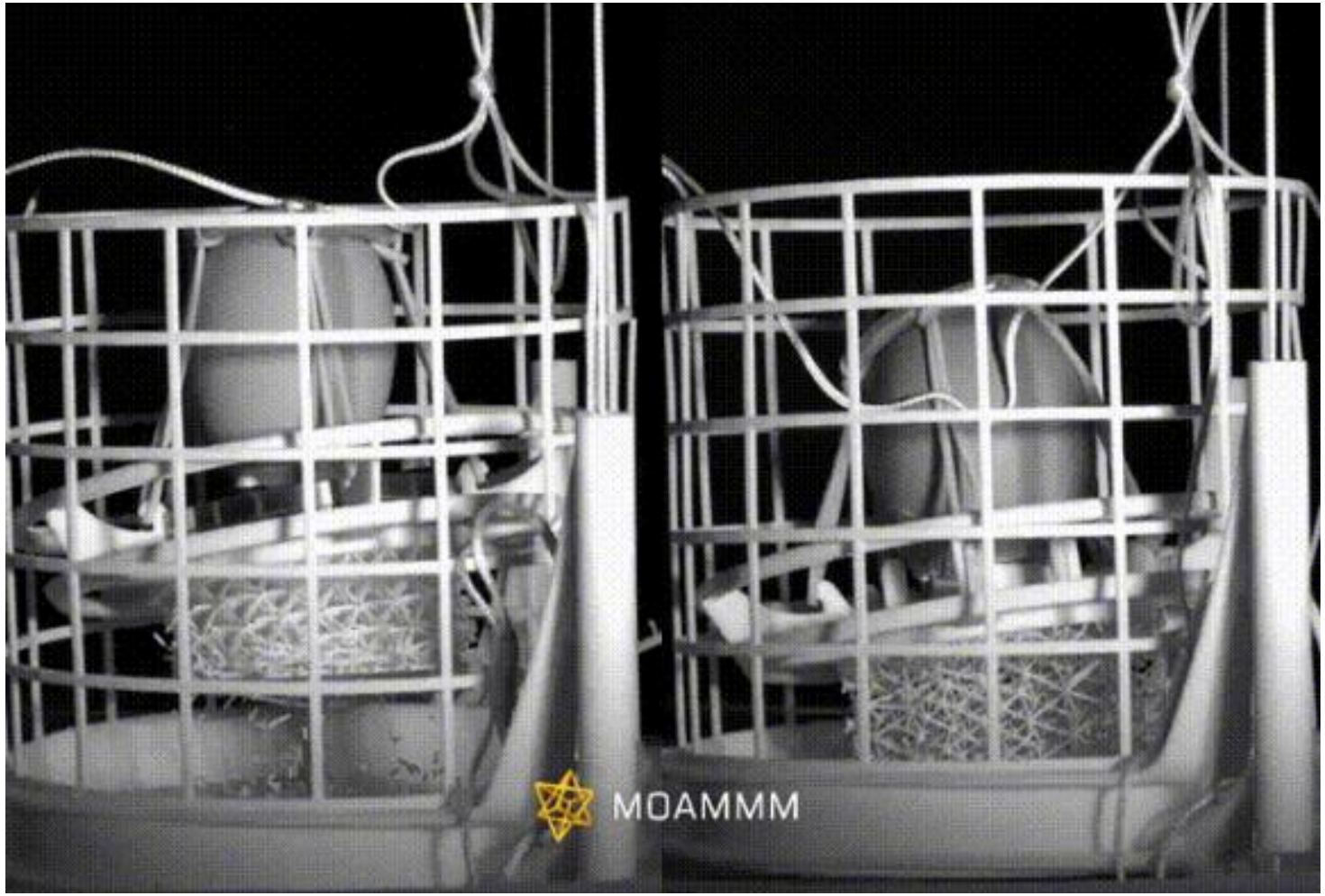
Was sind Lattice Strukturen?



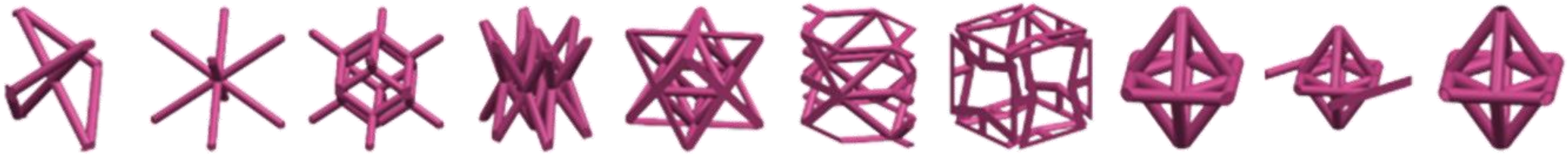
Multiple advantages e.g.:

- Light weight with high stiffness
- energy absorption capabilities



Lattices are assemblies of patterned cells

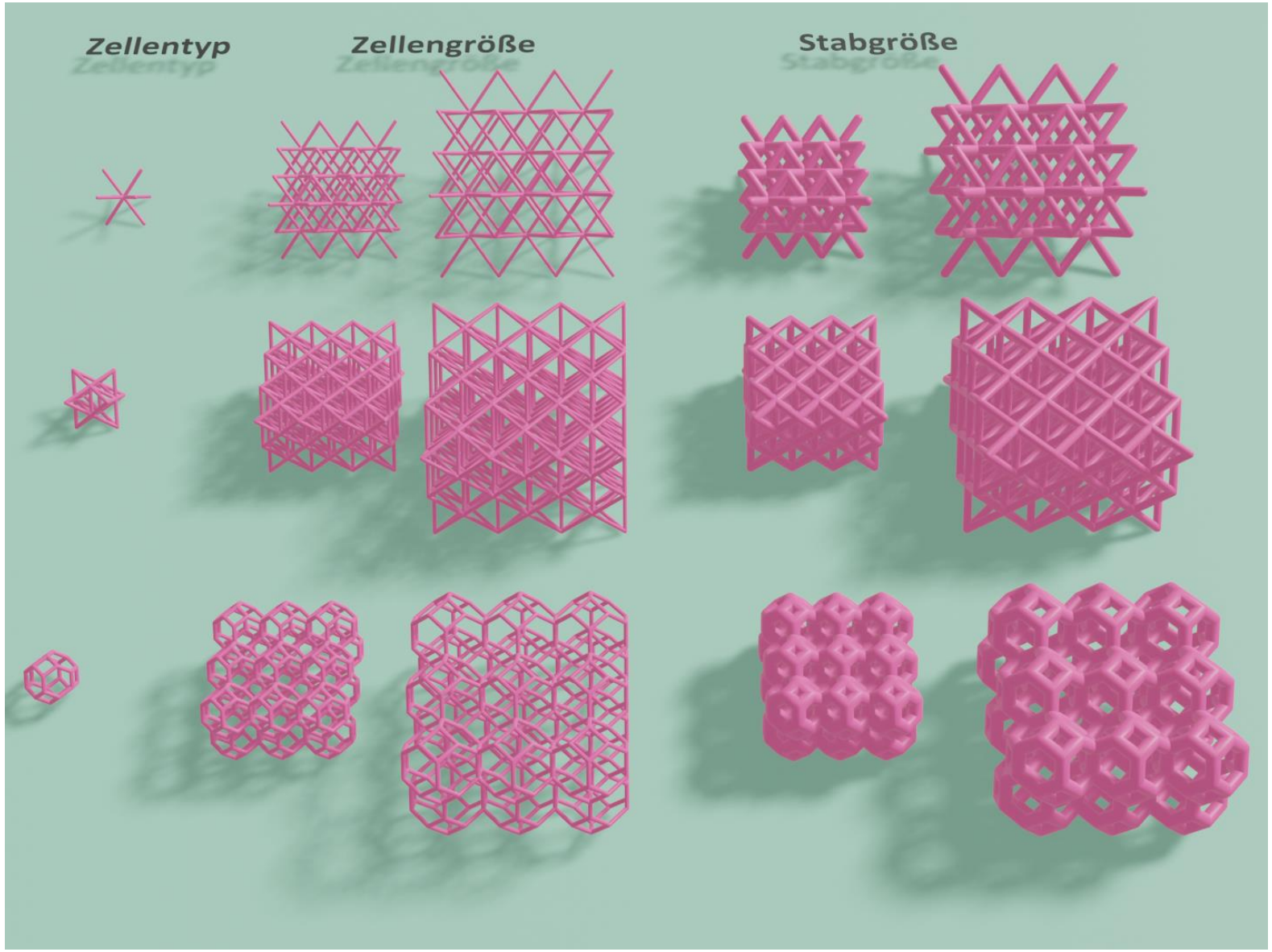
– Examples of cells



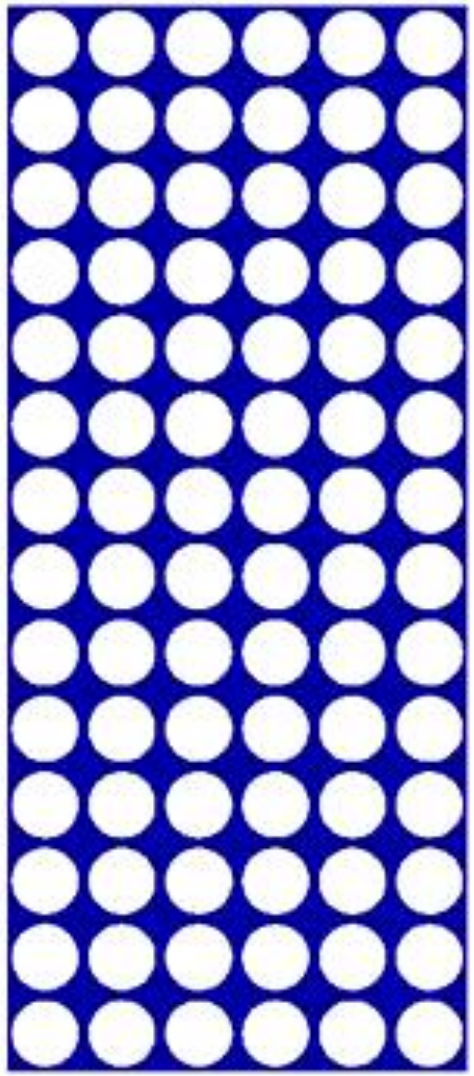
– Printed lattices

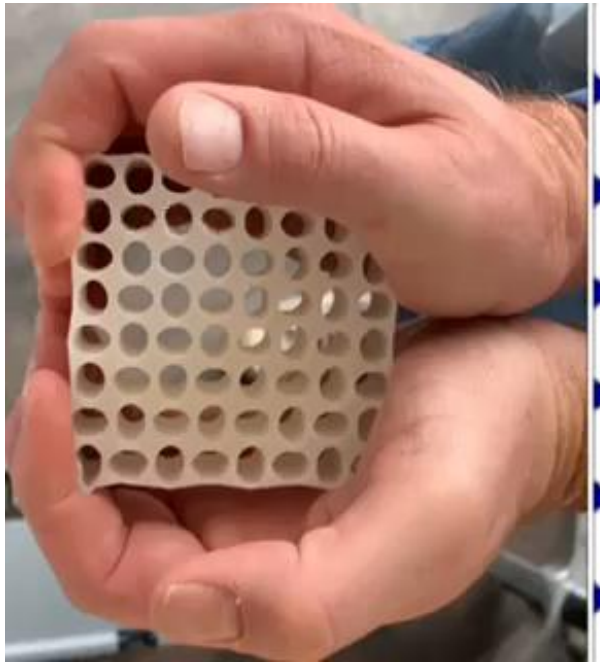
Lattices

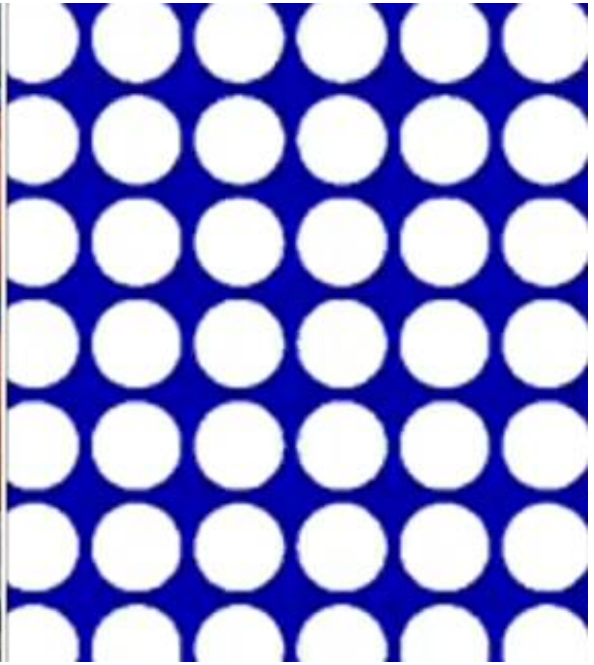
- Lattices parameters:
  - Cell type
  - Cell size
  - Strut dimensions



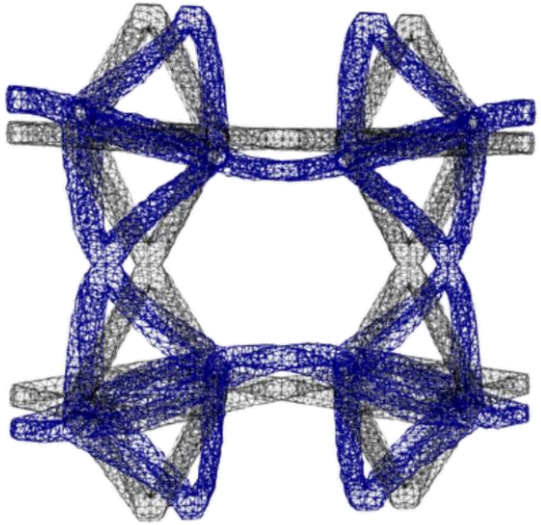
- Metamaterials are designed micro-structures that achieve new properties
  - Example: patterning change upon deformation

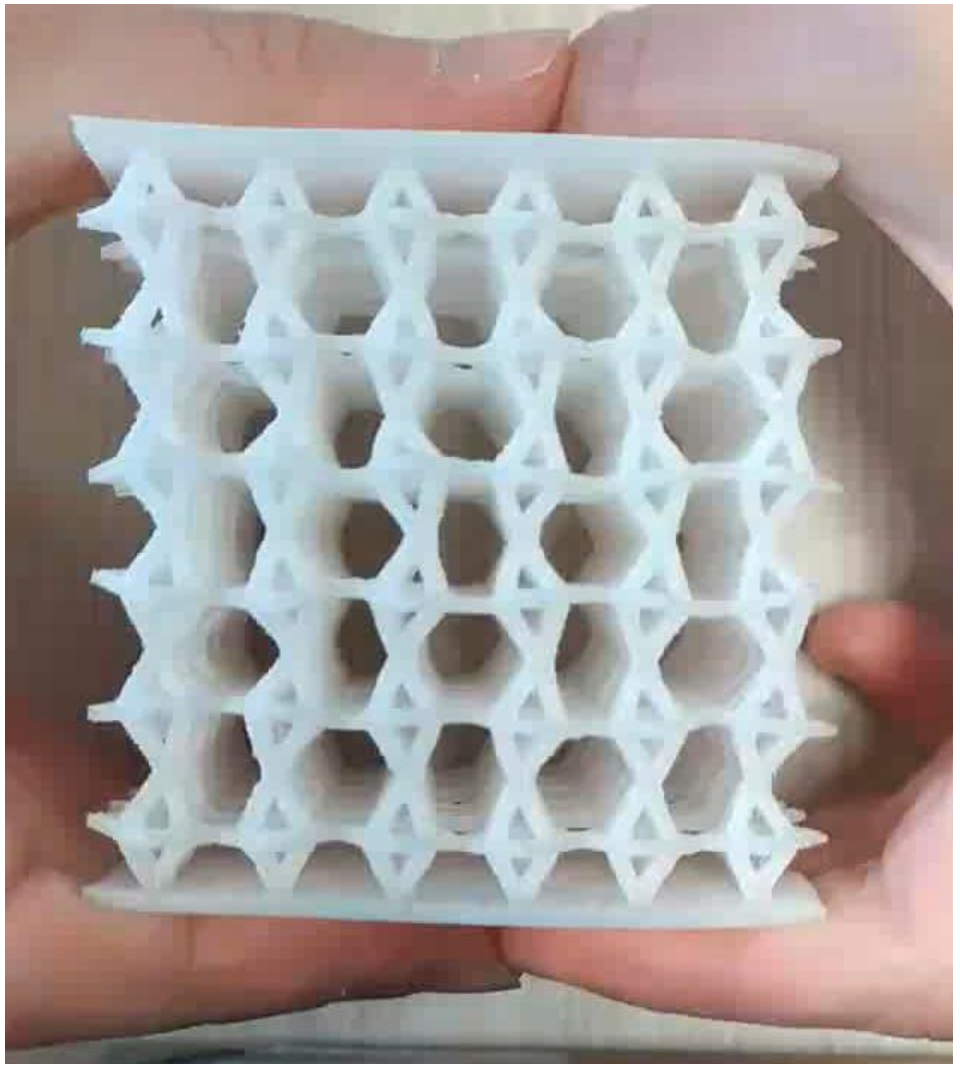






Simulation of Metamaterial Lattices



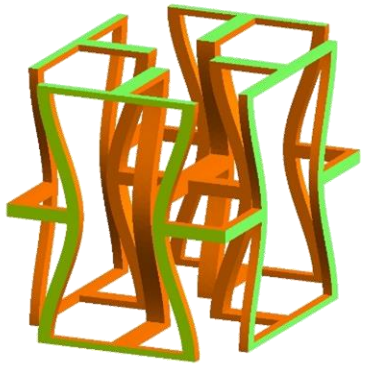


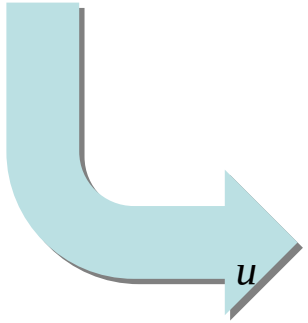
Change of patterning

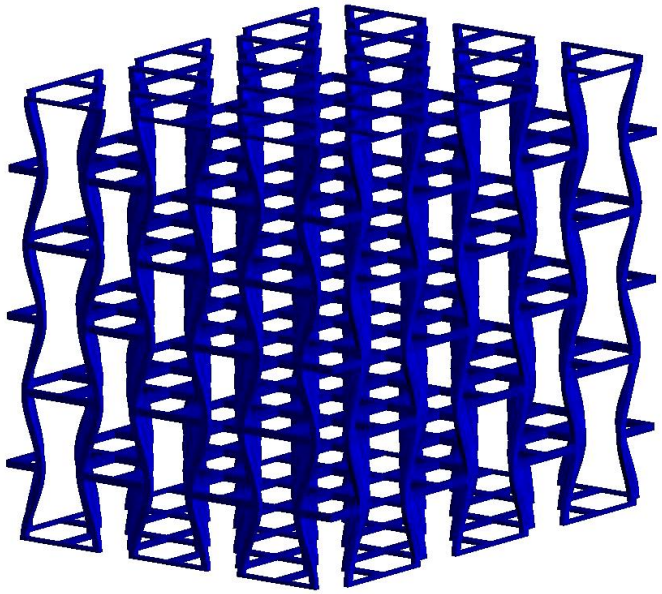
- predicted by simulation

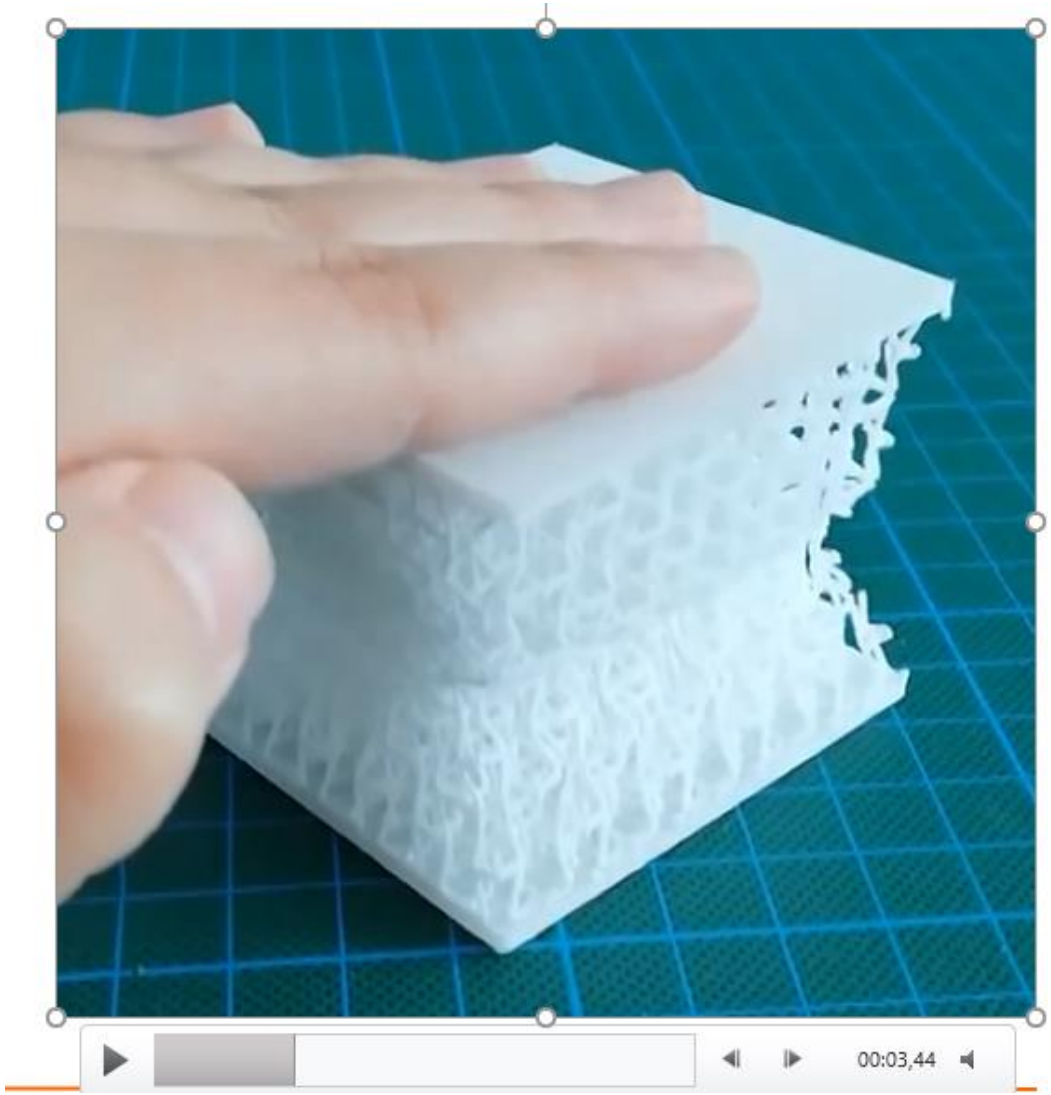
and

- experimentally observed





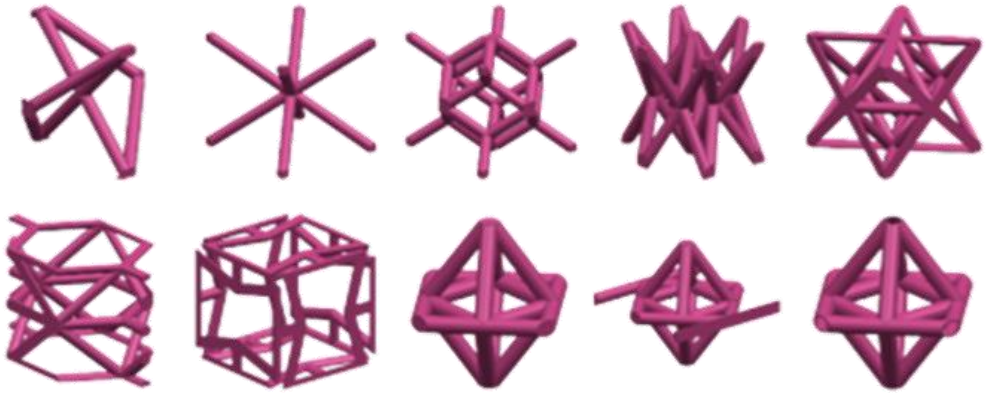




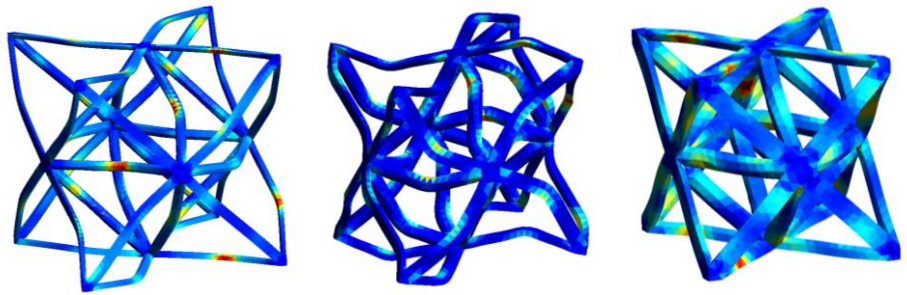
Auxetic structures (negative Poisson’s ratio)

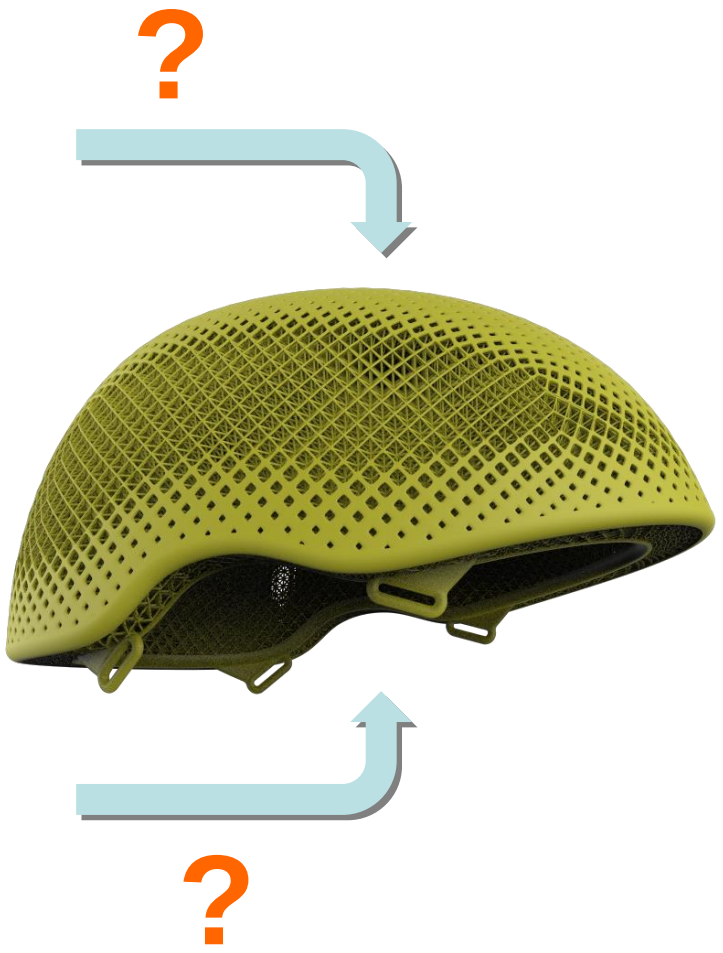
Optimise the cells for targeted applications

– Cell selection &



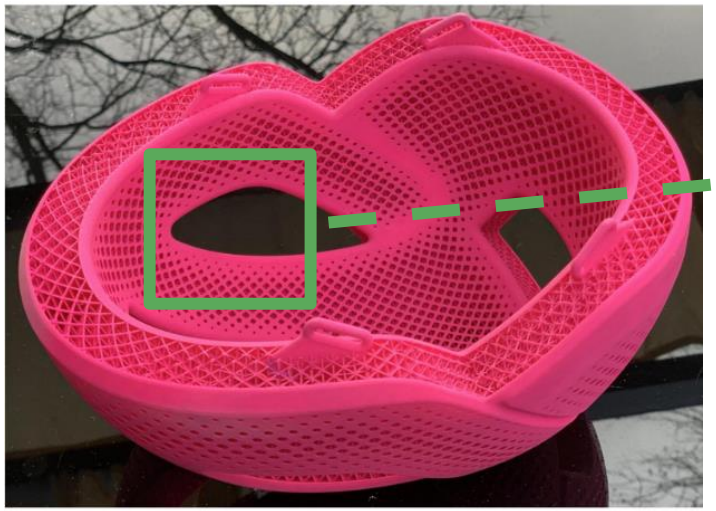
– Spatial distribution of cell parameters



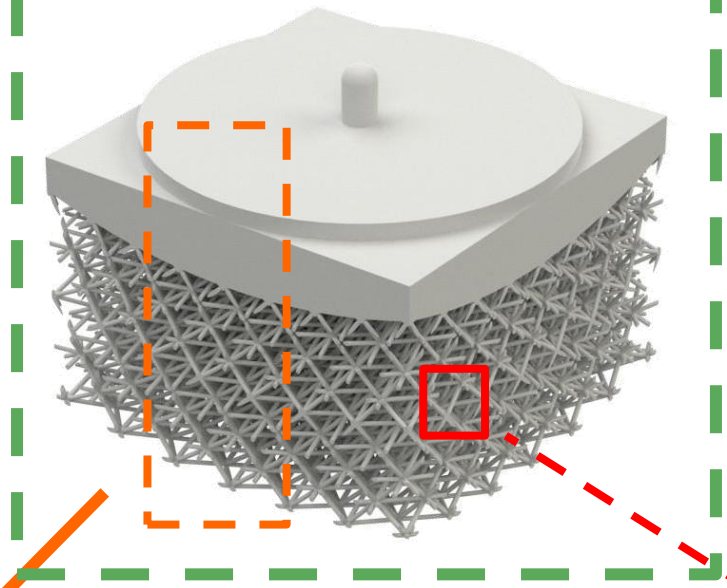


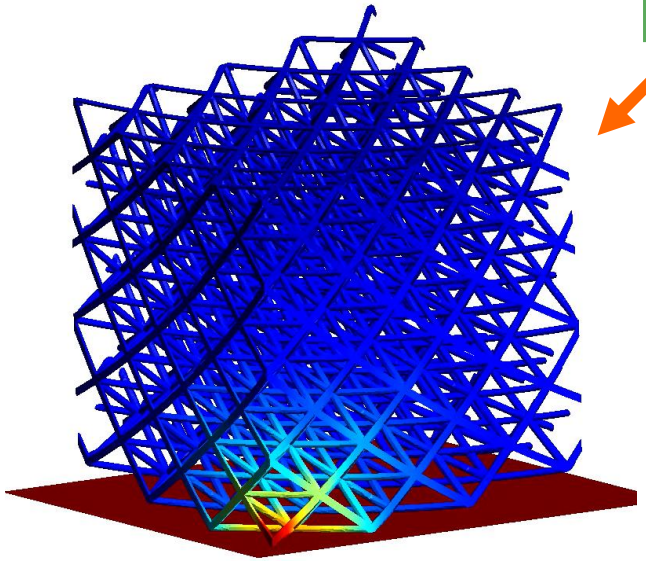
Too many parameters for optimisation

Accelerate the simulations



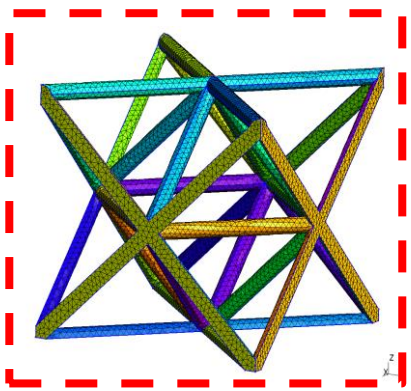
Helmet part : Lattice



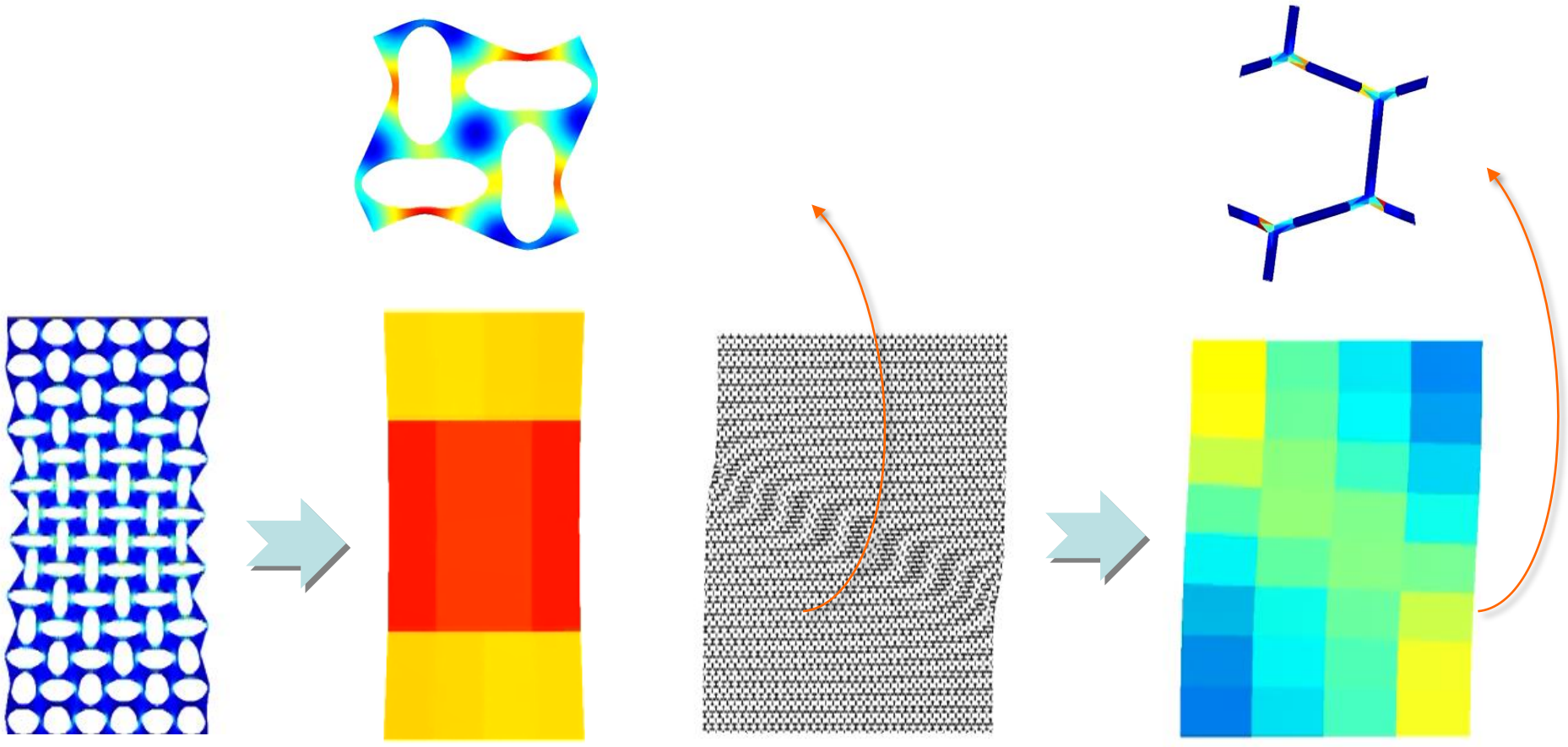


Simulation on ¼ of the sub-Lattice Helmet

Unit cell



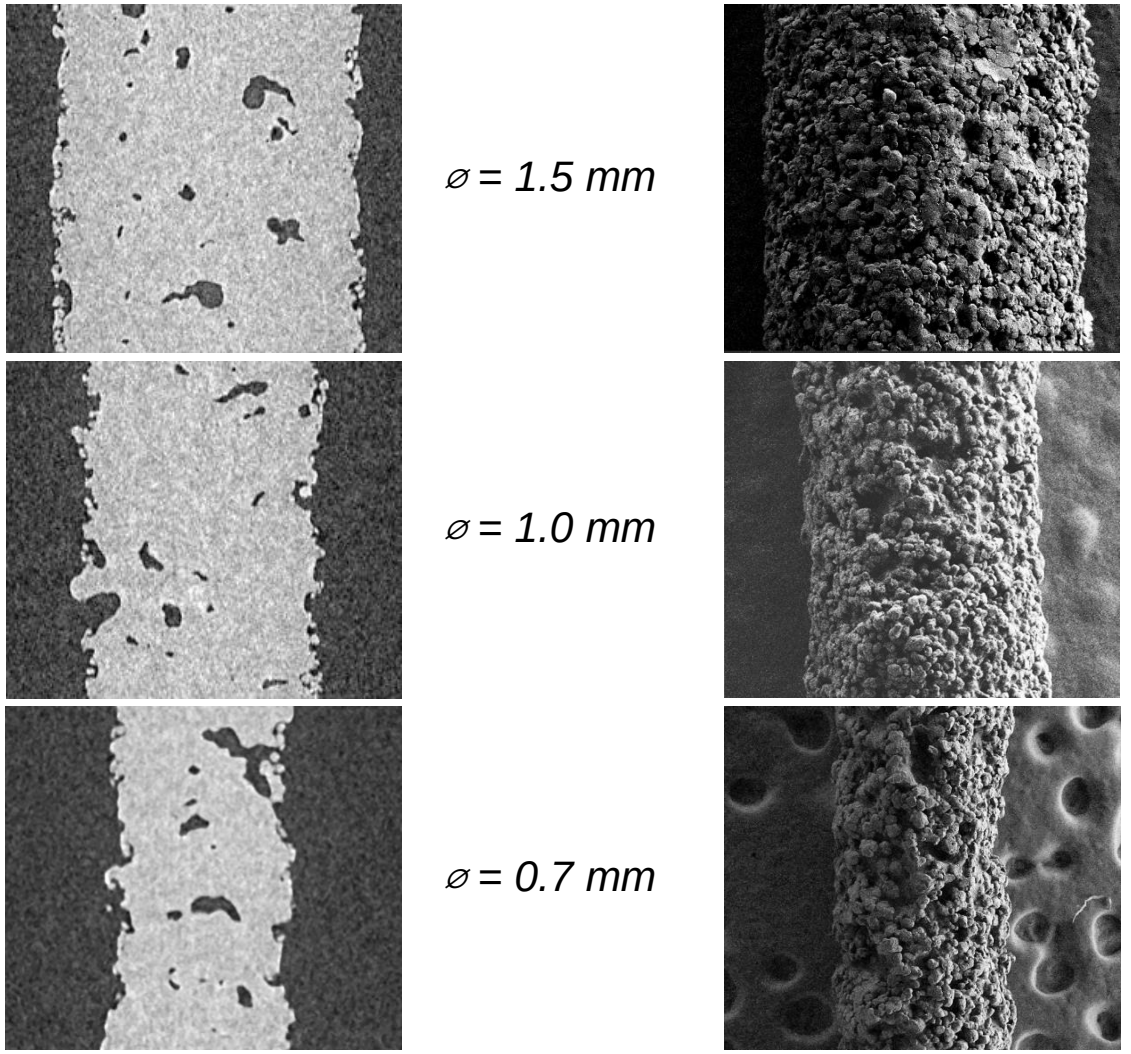
Accelerate the simulations with homogenisation



Still too expensive

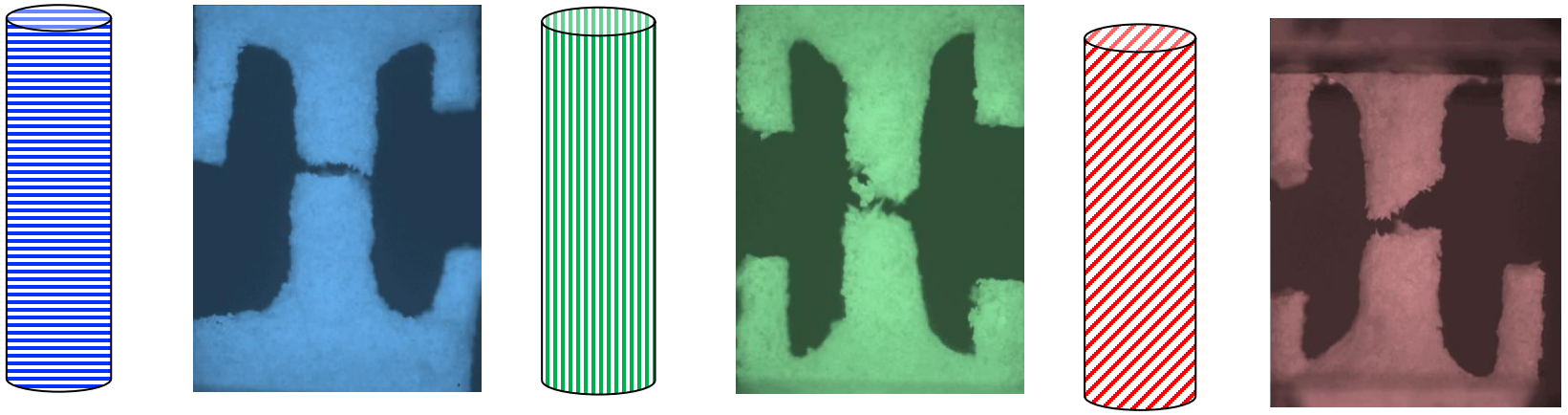
Why multiscale characterization?

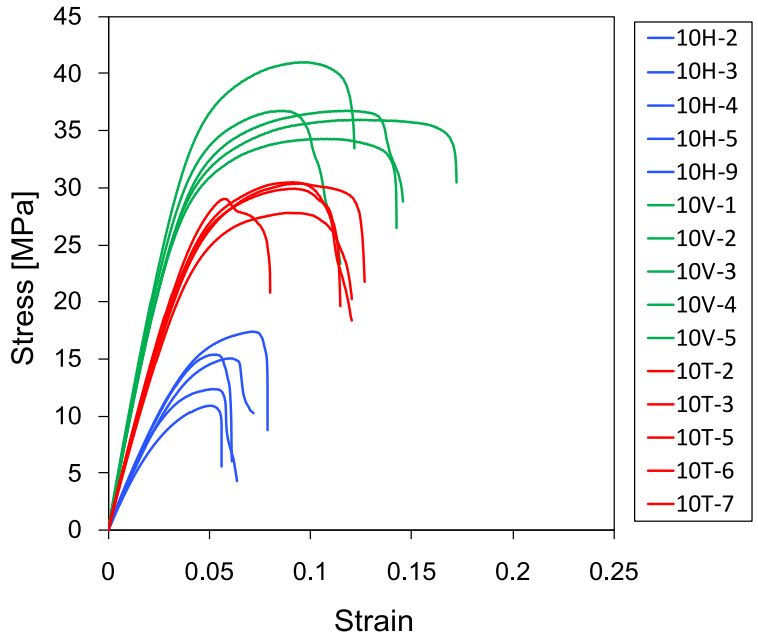
AM parts present defects: porosity and surface roughness

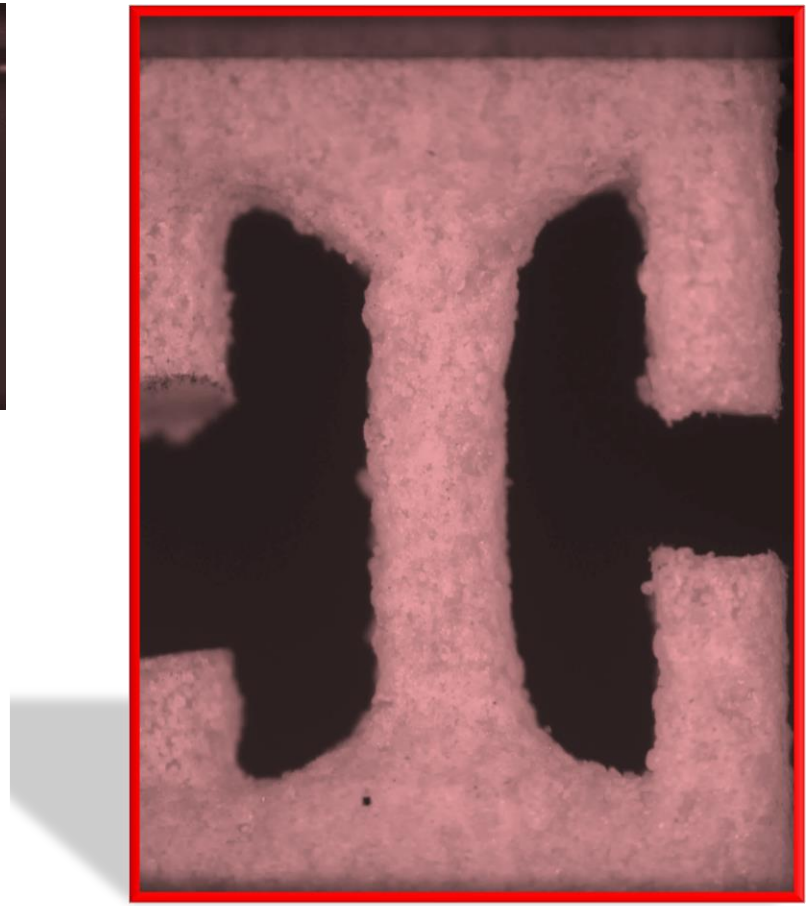


The magnitude of these defects and its effect on the performance depends on the AM process parameters and specimen size: strut diameter

Mechanical response of struts (1mm diameter)



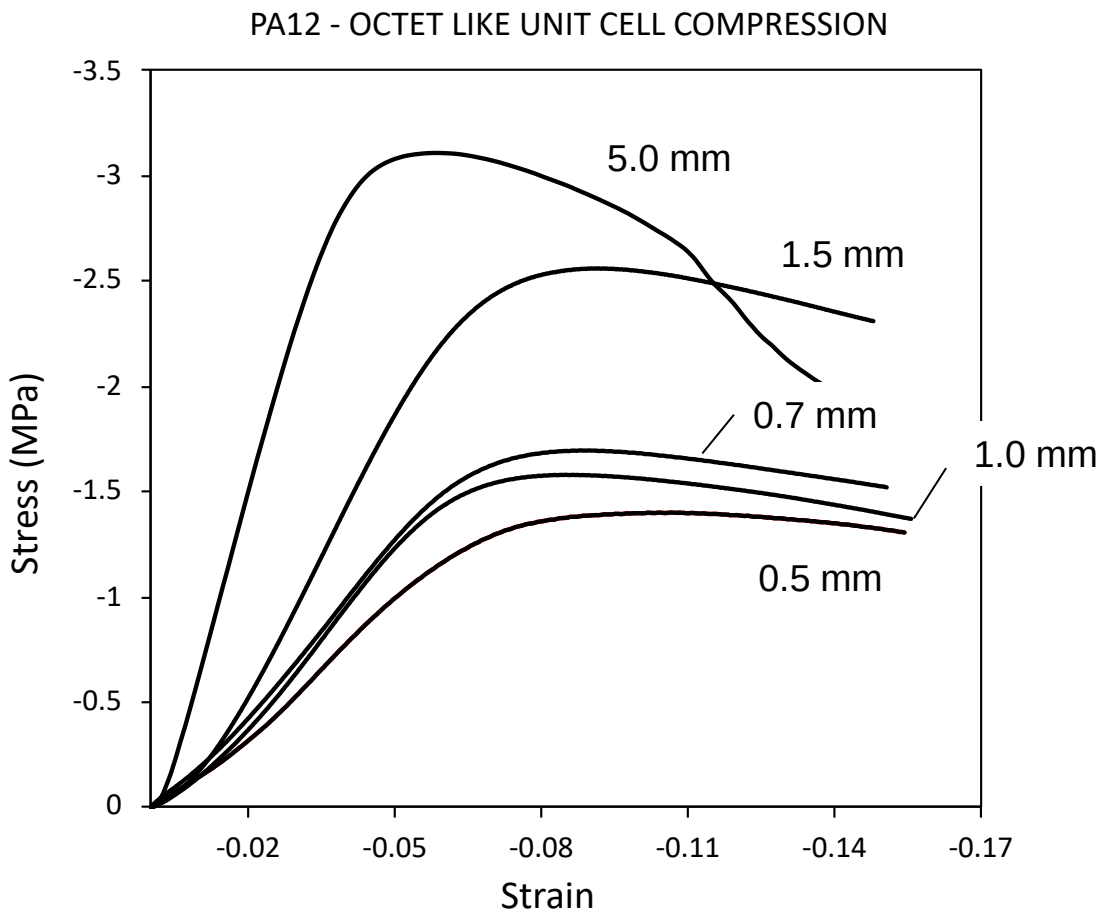


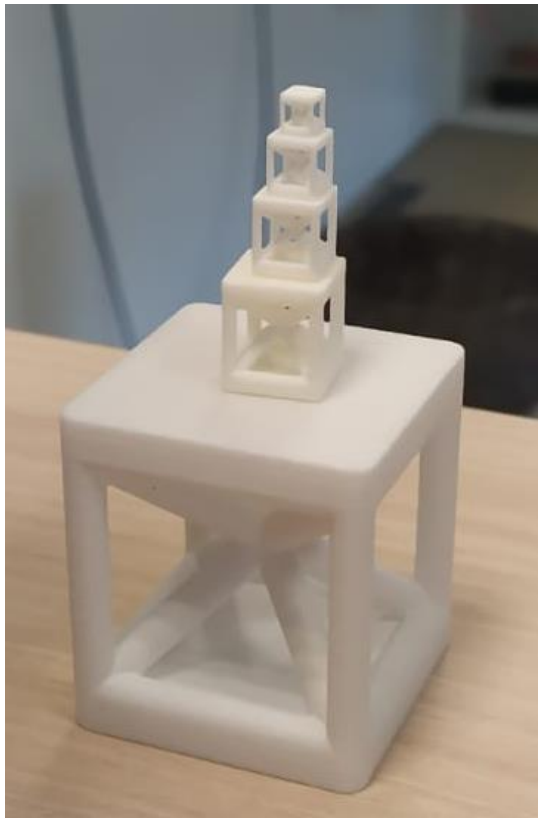


AM parts present defects: porosity and surface roughness

Size effects in the response of unit cells (OCTETS)

As conclusion, the relevant response of a big lattice can be totally different to a mm size one:



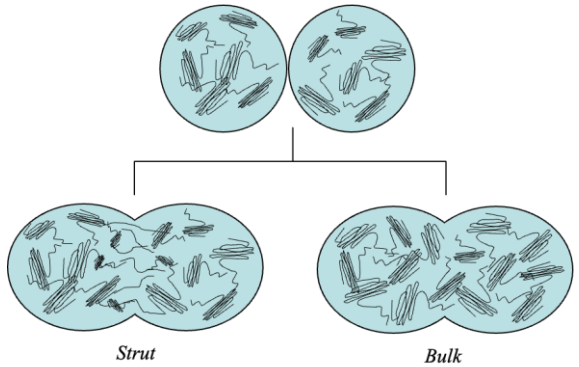


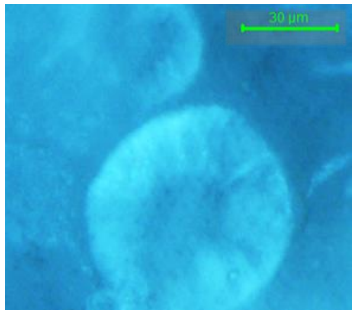
∅ (mm)	5	1.5	1.0	0.7	0.5
Stiffness (MPa)	**84**	44.1	28.8	29.0	21

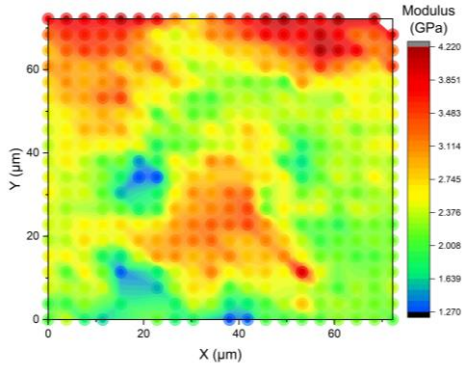
Why multiscale characterization?

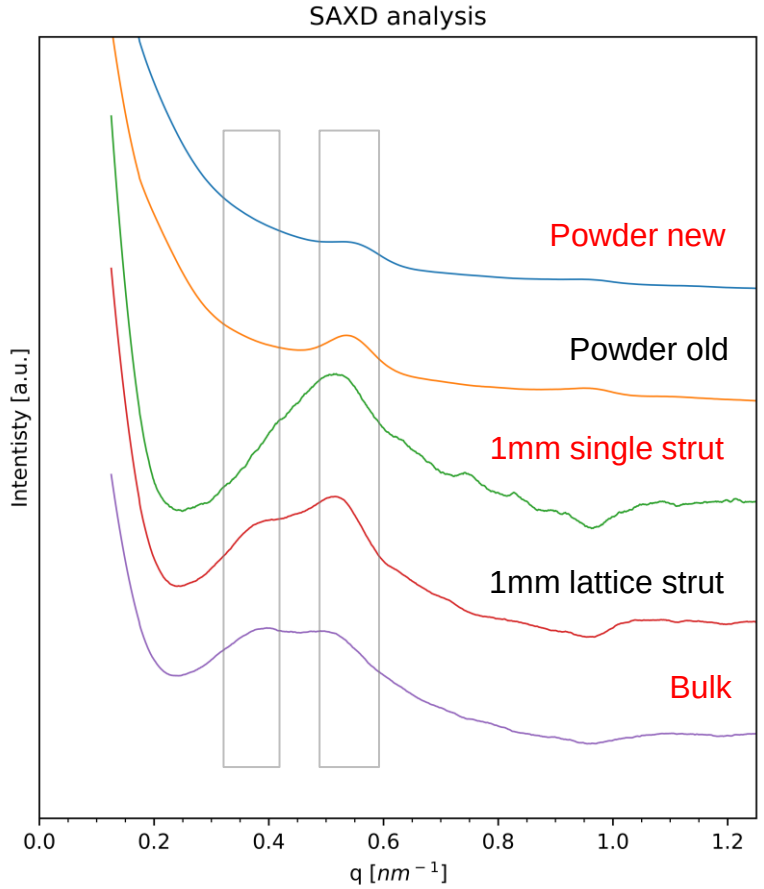
AM parts microstructure is strongly linked with the thermal history which depends on the specimen size

> different molecular structure









In polymeric materials, the level of crystallinity or amount of unsintered powder depends on the process and influences the mechanical response

Enhanced model predictions

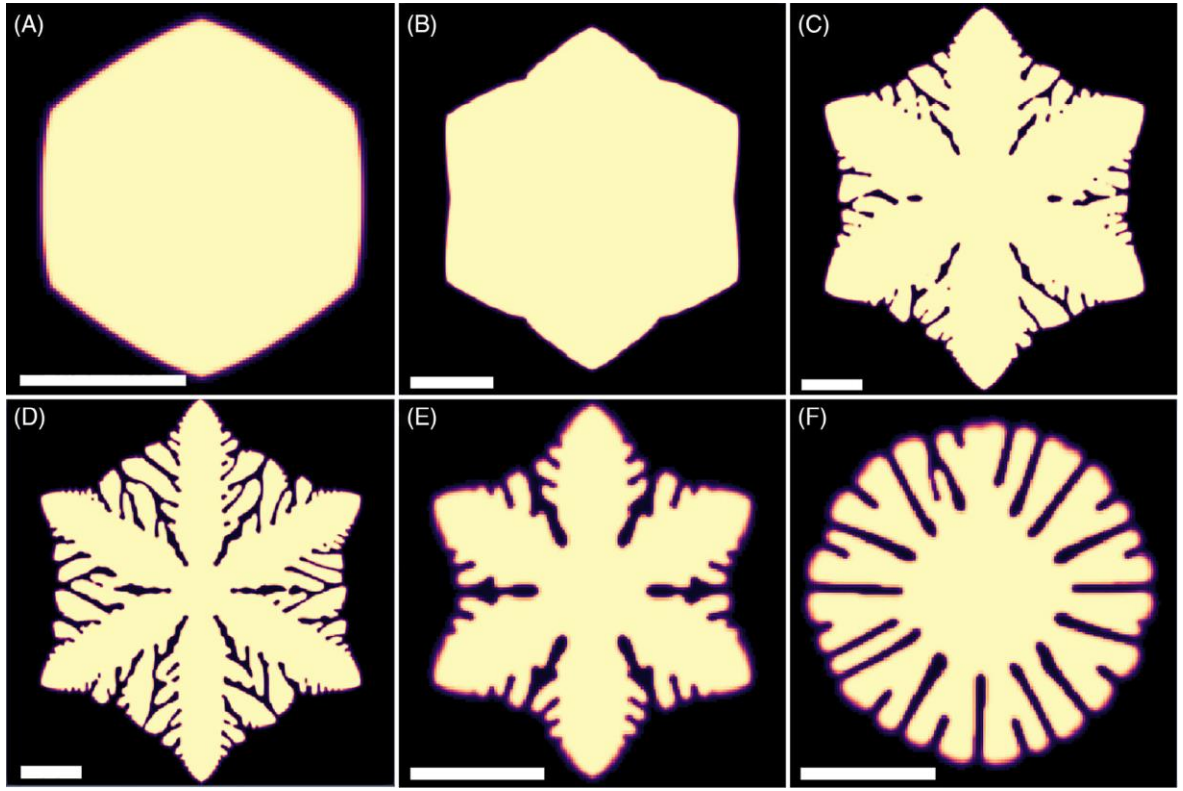


FIGURE 9 Simulation of changing the temperature effect for isotactic polystyrene with the proposed model of Equation (19). Mesh size $D = 10^{-7}$m. (A) T_c = 210°C, 4 h, (B) T_c = 205°C, 4 h, (C) T_c = 200°C, 4 h, (D) T_c = 195°C, 3 h, (E) T_c = 190°C, 1 h, and (F) T_c = 180°C, 1 h. Scale bars are 5 μm. Model parameters in Table 1

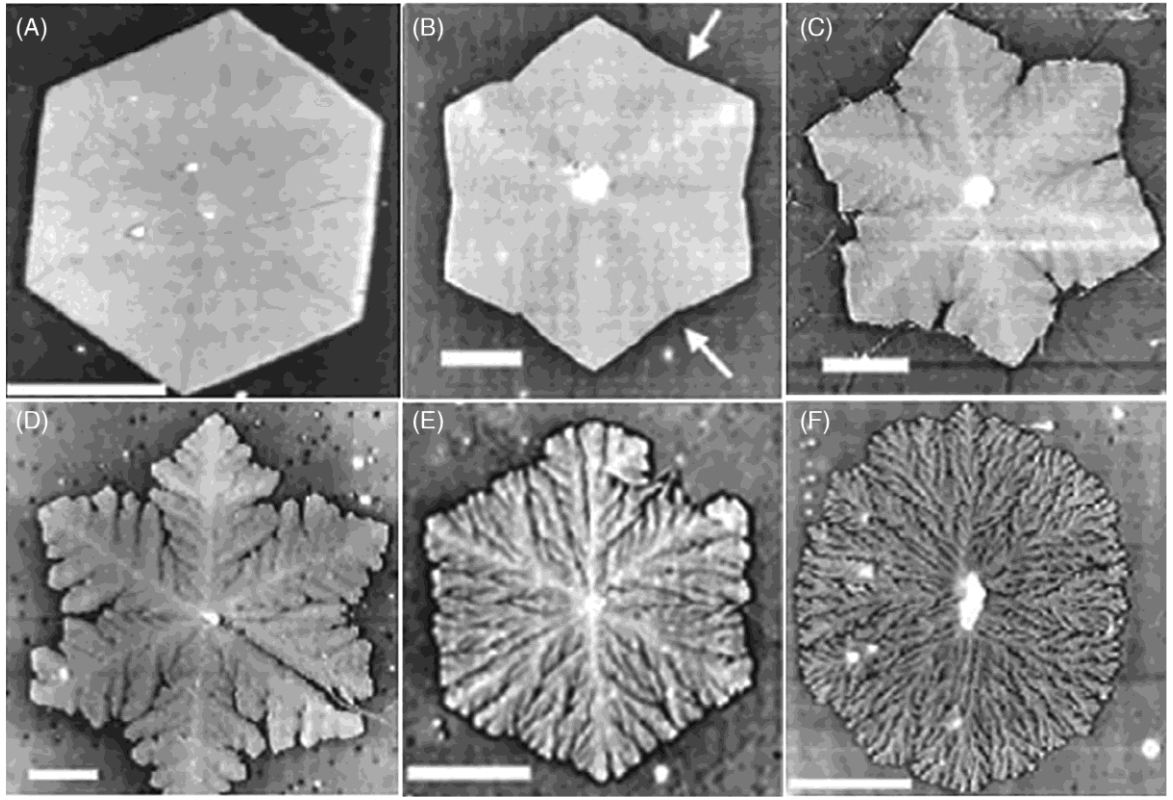
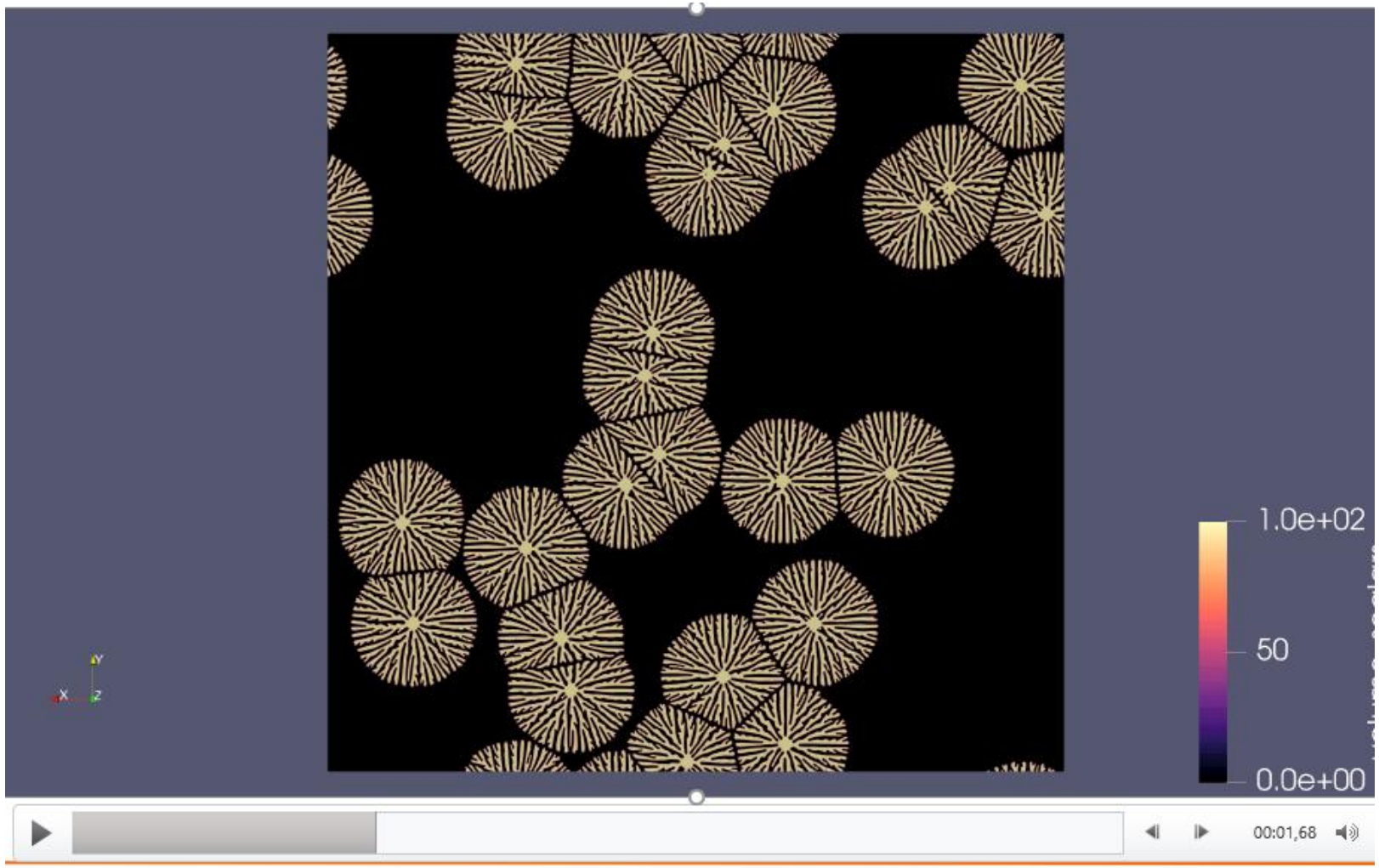


FIGURE 1 Experimental results[4] for isotactic polystyrene on the effect of crystallization temperature. (A) T_c = 210°C, 4 h, (B) T_c = 205°C, 4 h, (C) T_c = 200°C, 4 h, (D) T_c = 195°C, 3 h, (E) T_c = 190°C, 1 h, and (F) T_c = 180°C, 1 h. Scale bars are 5 μm

Consistency between the enhanced model predictions and experimental results

Enhanced model predictions

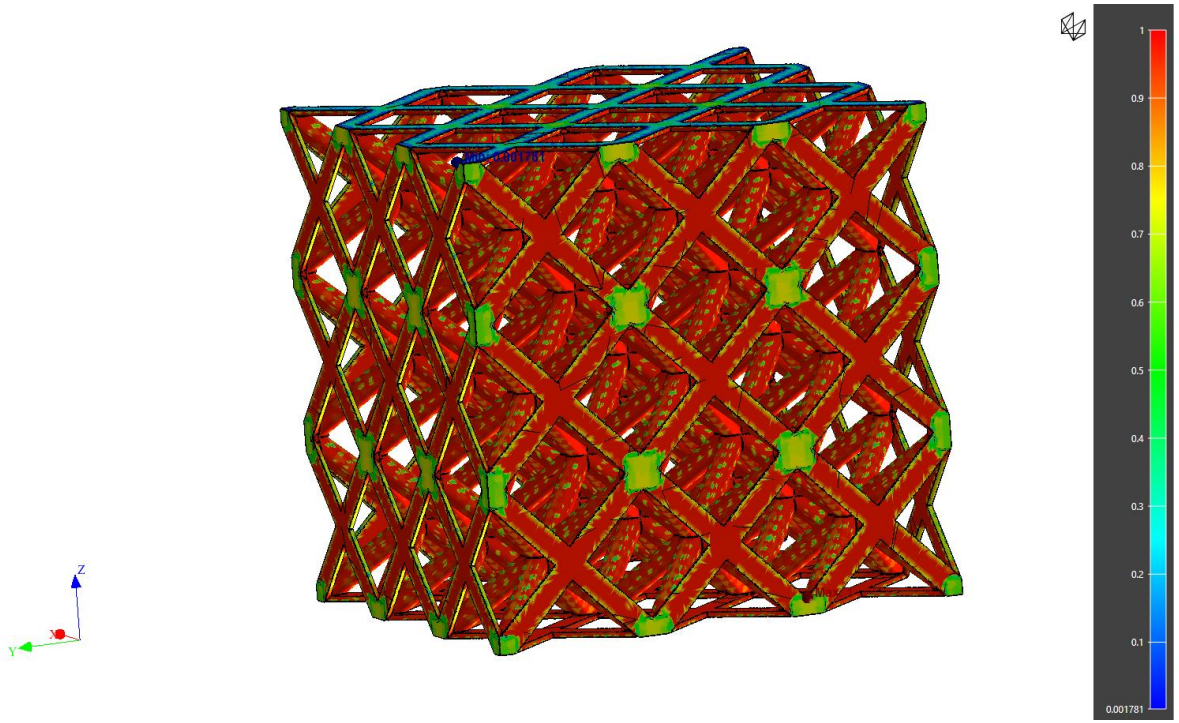
2D simulation with multiple nucleations

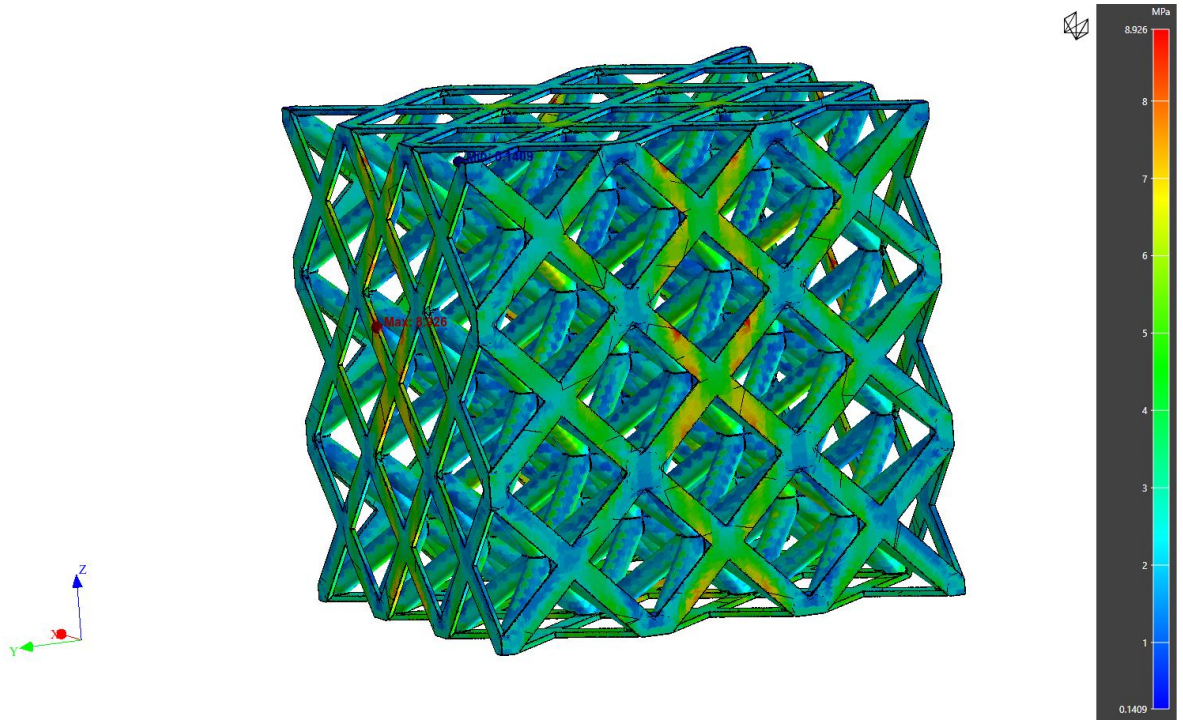


Numerical 2D simulation of polymer crystallization [Bahloul, Doghri, Adam, 2020]

Model of lattice cell printing

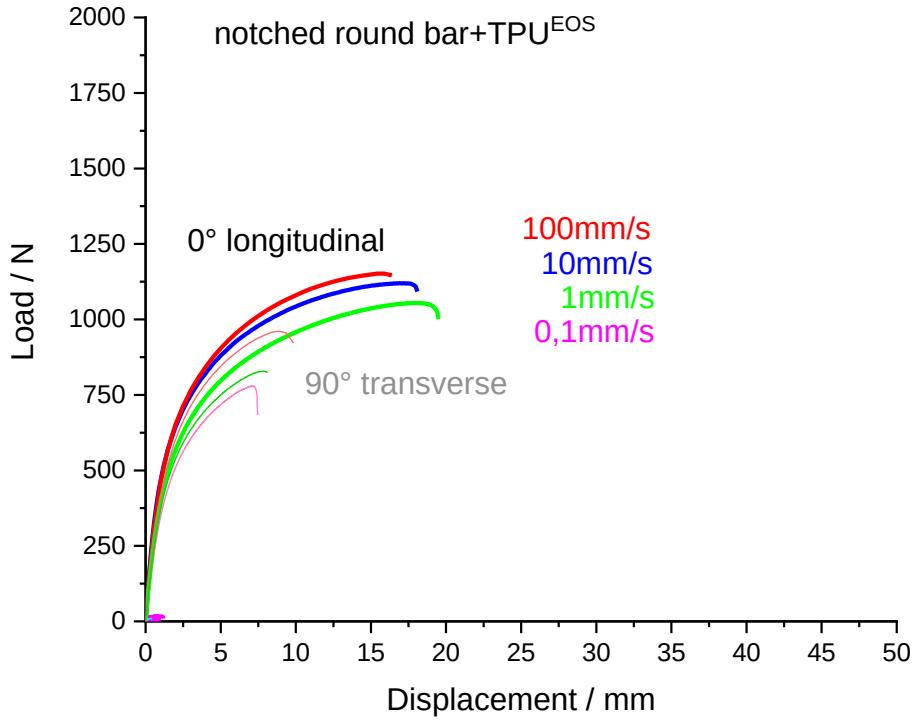
- Lattice structure printing
  - Christianity ratio
    - From 40% to 100% (fully crystalline)
    - Consistent results with experimental measurements from IMDEA ($\approx 45\%$)
  - Residual stresses
    - From 0 to 9 MPa
    - Can be exported to be accounted for in multi-scale optimization



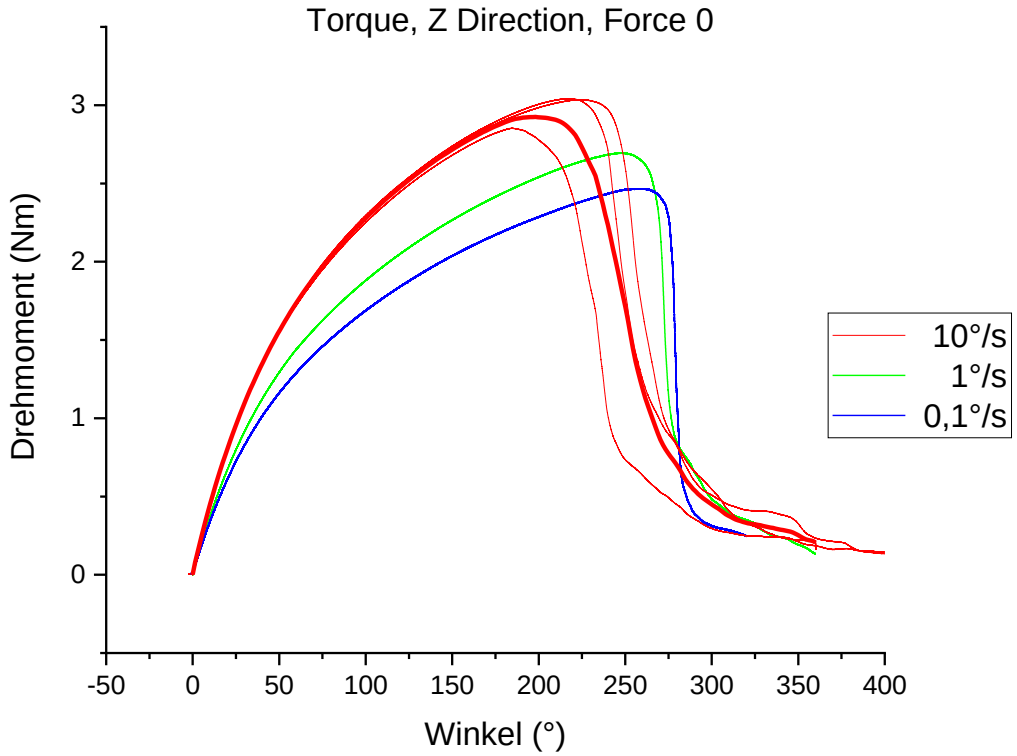


Monotonic tests

Tensile Tests of Bulk SLS Specimens

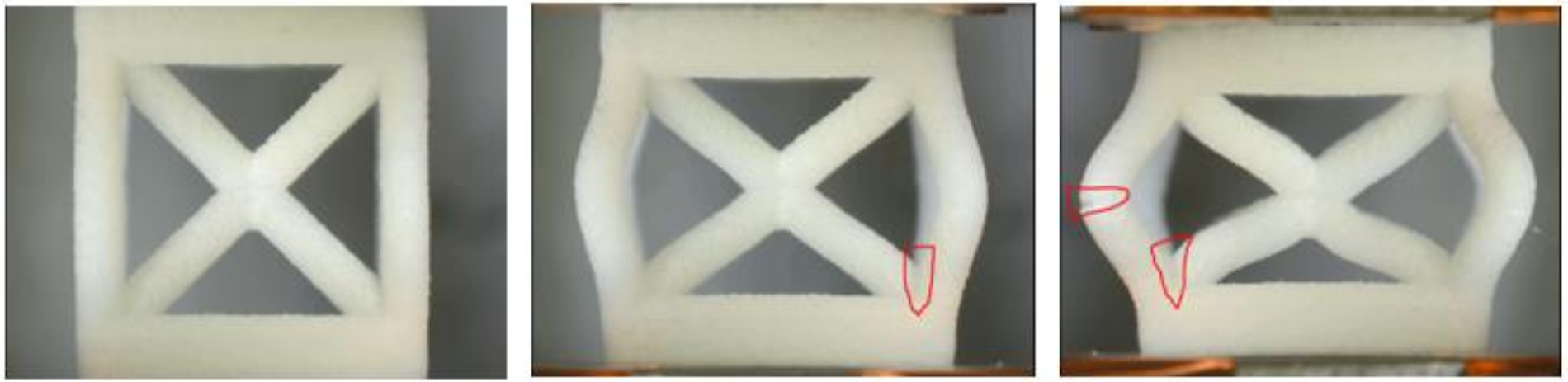


Torsion tests

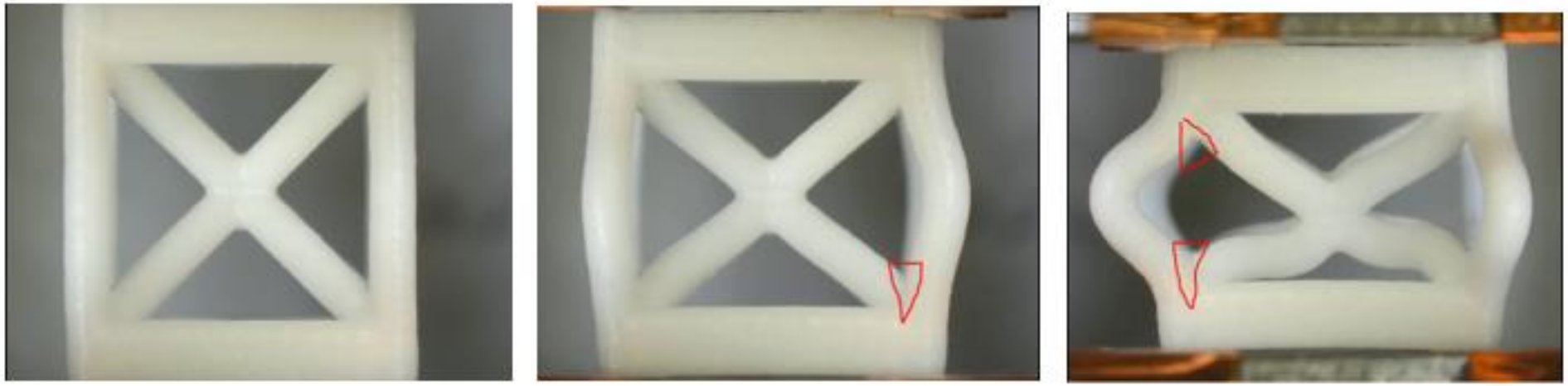


Damage model application on unit cell

Experimental compression test : **without** surface treatment.



Experimental compression test : **with** surface treatment.



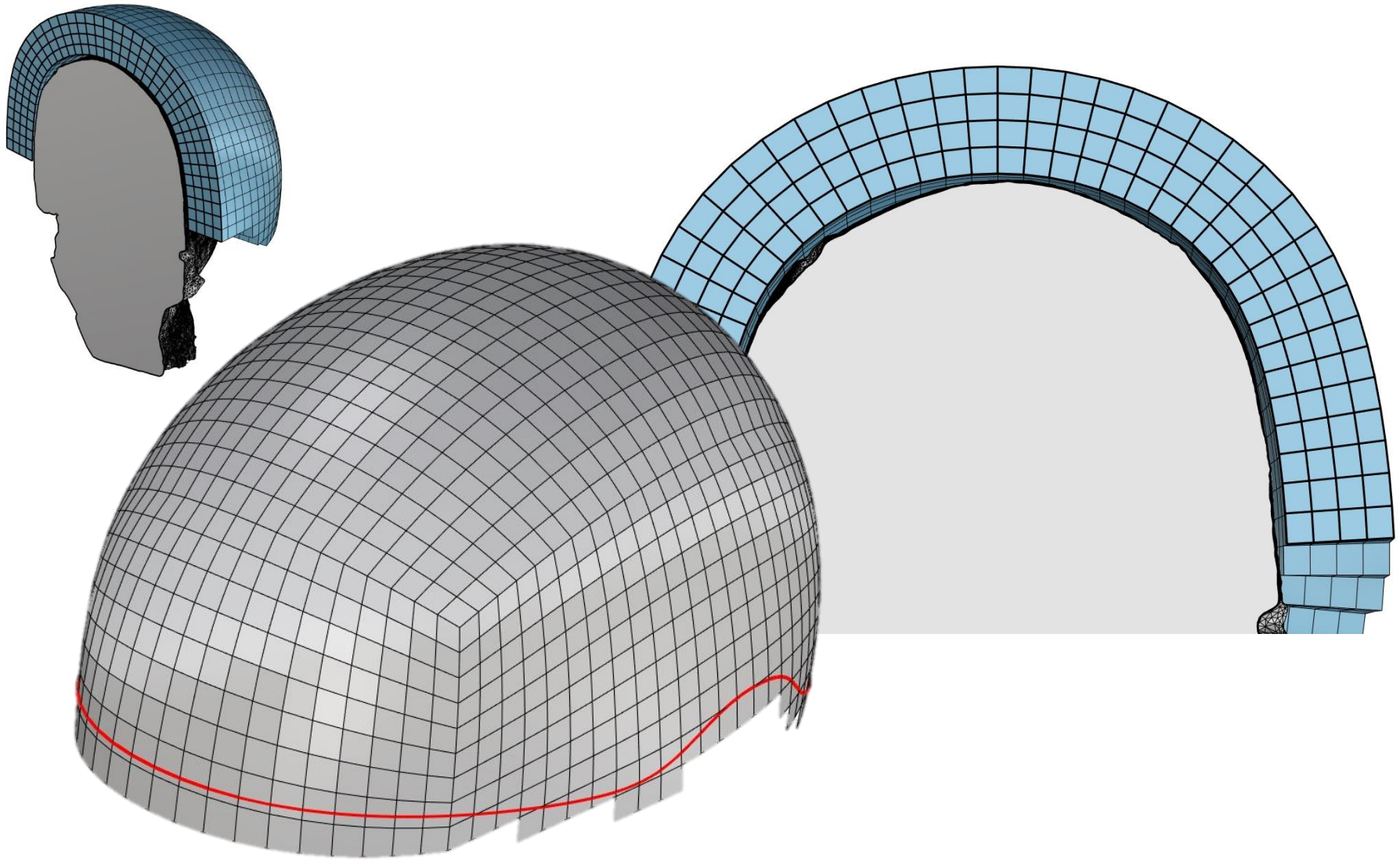
cirp helmet demonstrator/ cell grid current concept (section)

- **Prinzip:**

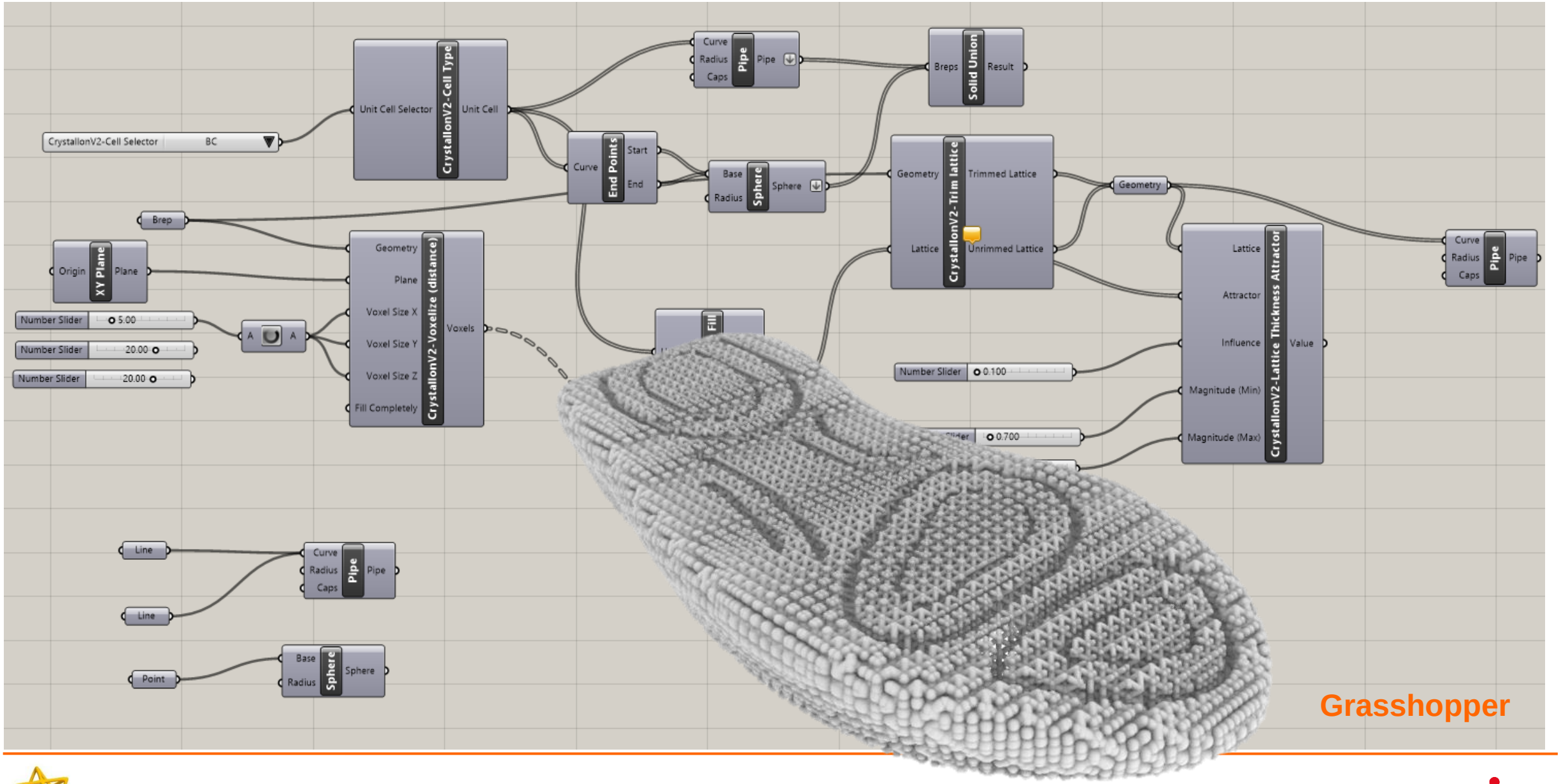
Innenseite ist Ausgangspunkt für die Zellerzeugung, alle Zellschichten sind gleich dimensioniert

- **Resultat:**

relativ präzise Zellen in der inneren Schicht, zunehmende Verzerrung nach außen – abhängig von der lokalen Krümmung



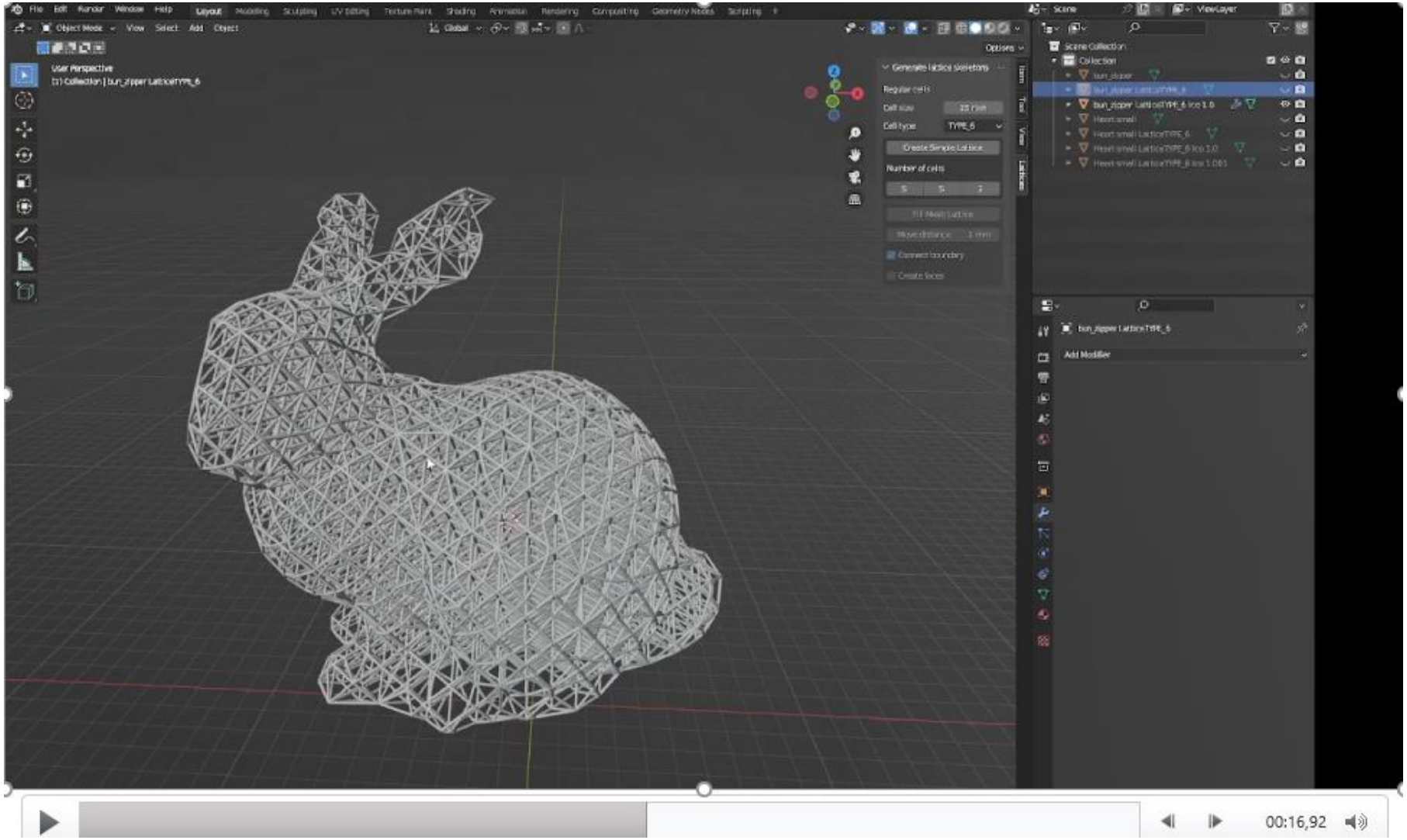
Optimised Application



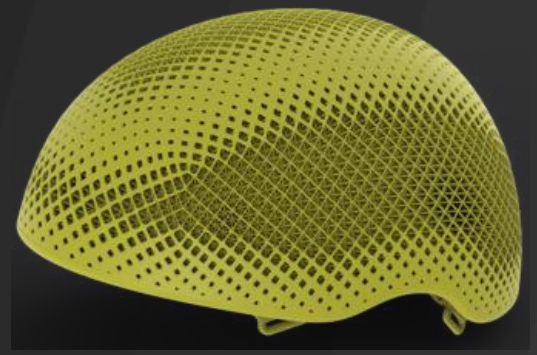
cirp´s propretary software tool „Lattesh“ / Lattice generation by a mouse click

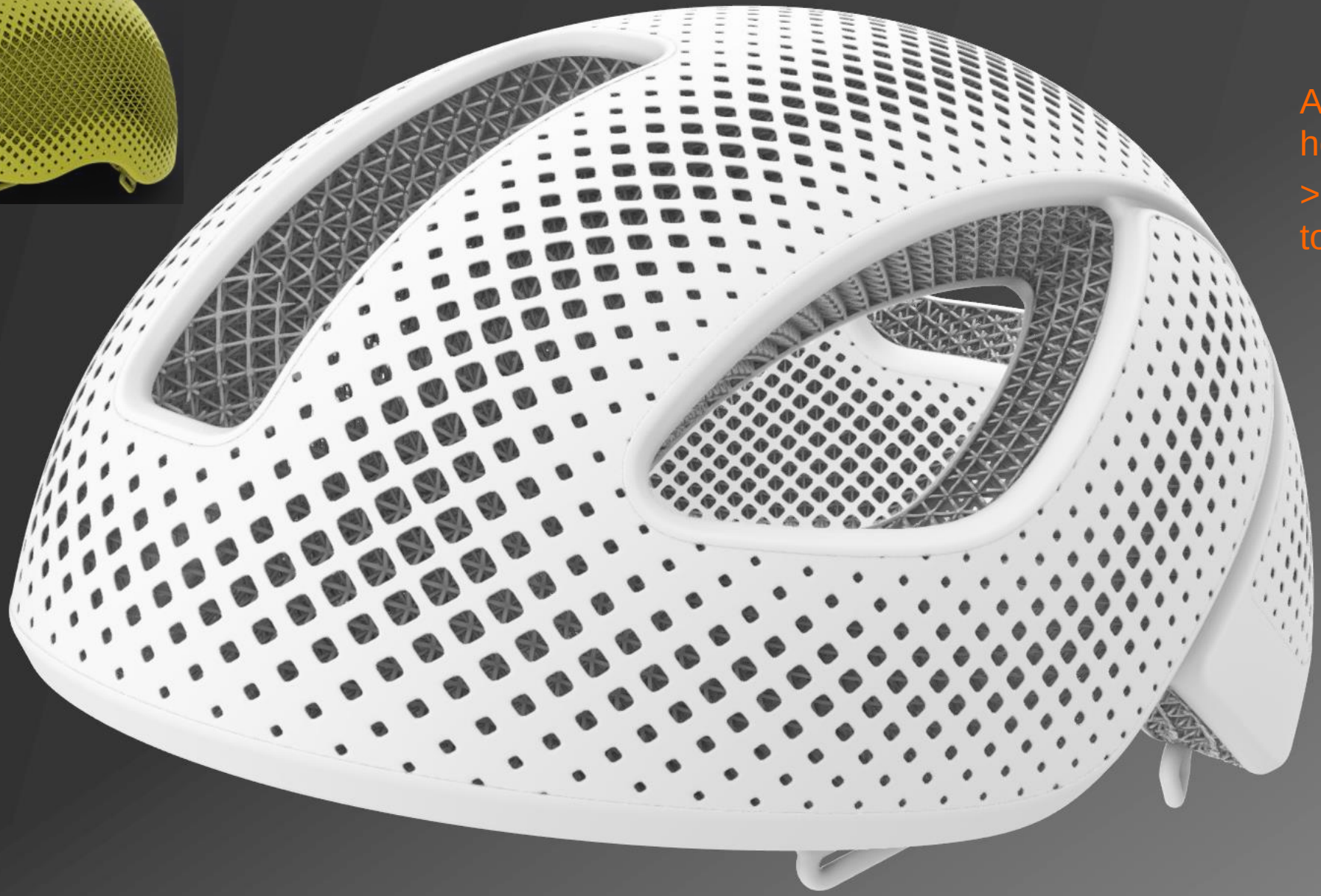
cirps Blender based **„Lattesh“** software tool

developed for fast and easy lattice generation



Helmet prototype with holed structure



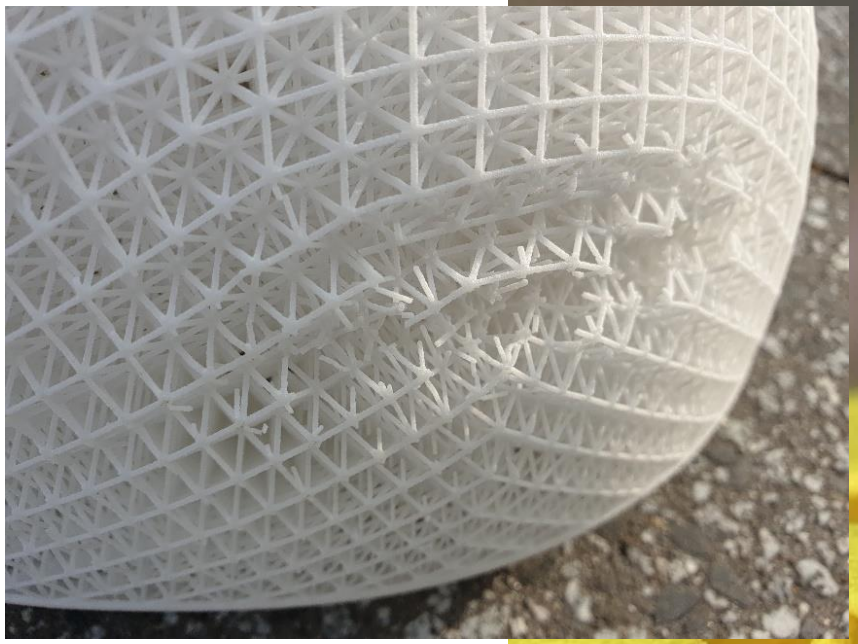


Application of holes

> main aim was to save weight

Lattice demonstrators in action

Smooth cutting of regular lattices



Thank you!