

# Prototyping and Virtual Testing of Sports and Work Helmets

16<sup>th</sup> LS-DYNA Forum 2022, Bamberg, Germany

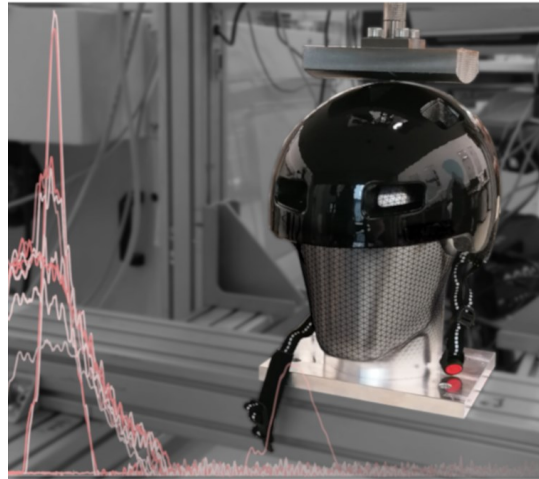
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<sup>2</sup>Senckenberg Gesellschaft für Naturforschung Dresden, Dresden

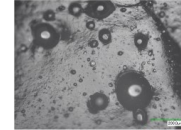
<sup>3</sup>UVEX SPORTS GROUP GmbH & Co. KG

# Motivation

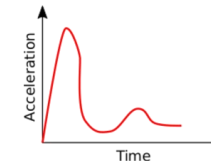
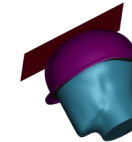
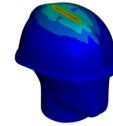


BioDASH - Bionisch Dämpfender  
Automatik-Schutzhelm

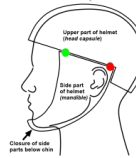
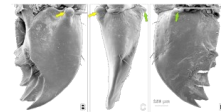
## Material



## Structure



## Mechanism



Aim: Improve helmet crashworthiness  
and functionality

Construction inspired by  
biological models

Virtual testing

Rapid prototyping via FDM

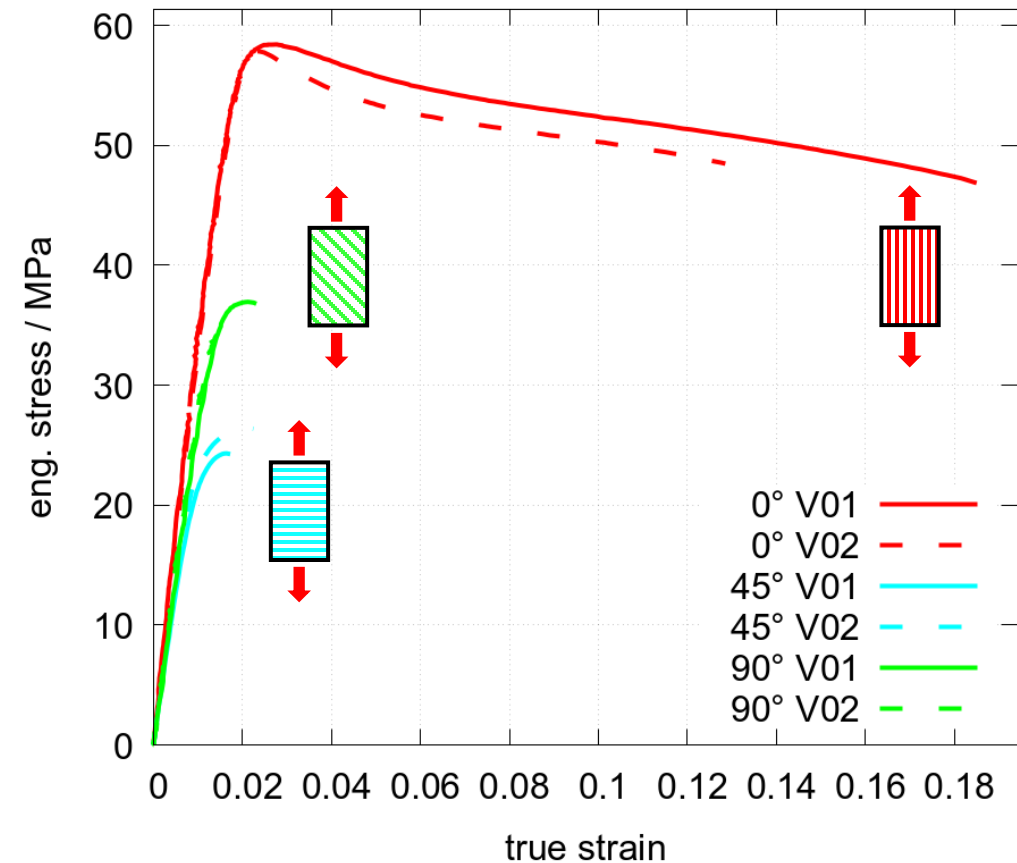
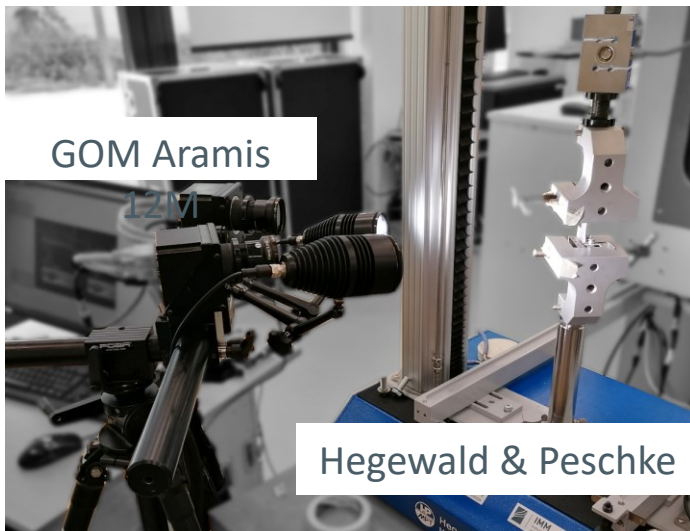
Prototype

Feedback loop

We acknowledge financial support within the BMBF program "Biologisierung der Technik" for the project "BioDASH-Bionisch Dämpfender Automatik-Schutzhelm".

## Tensile Test

- BZ specimen geometry<sup>1</sup>,  $t = 3 \text{ mm}$
- $0.1 \text{ mm/s}$

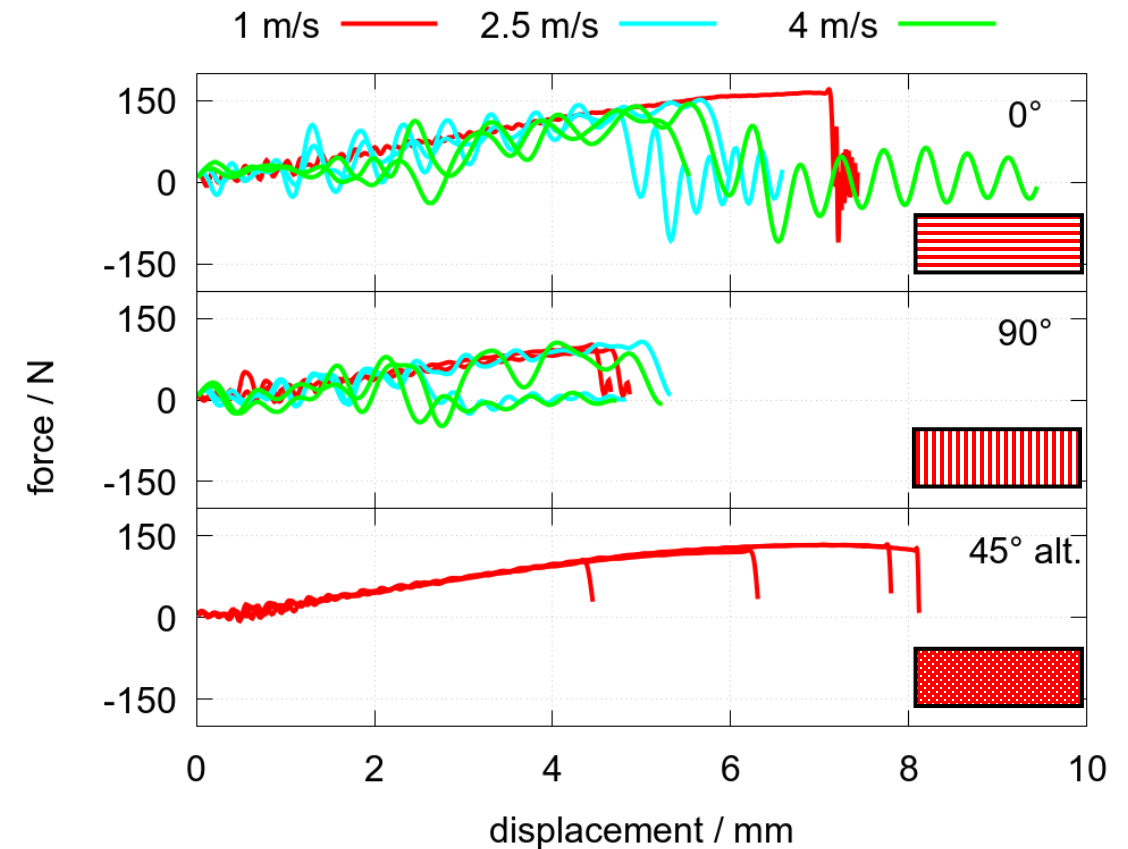
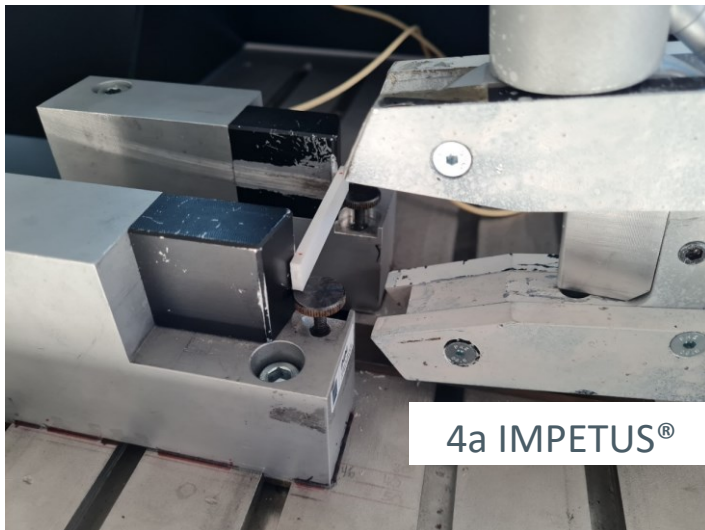


<sup>1</sup>F. Becker, *Entwicklung einer Beschreibungsmethodik für das mechanische Verhalten unverstärkter Thermoplaste bei hohen Deformationsgeschwindigkeiten* (Martin-Luther-Universität Halle-Wittenberg, 2009).

# Acrylonitrile Butadiene Styrene (ABS)

## 3 Point Bending Test

- Specimen size: 60 x 10 x 3 mm
- 1, 2.5 and 4 m/s

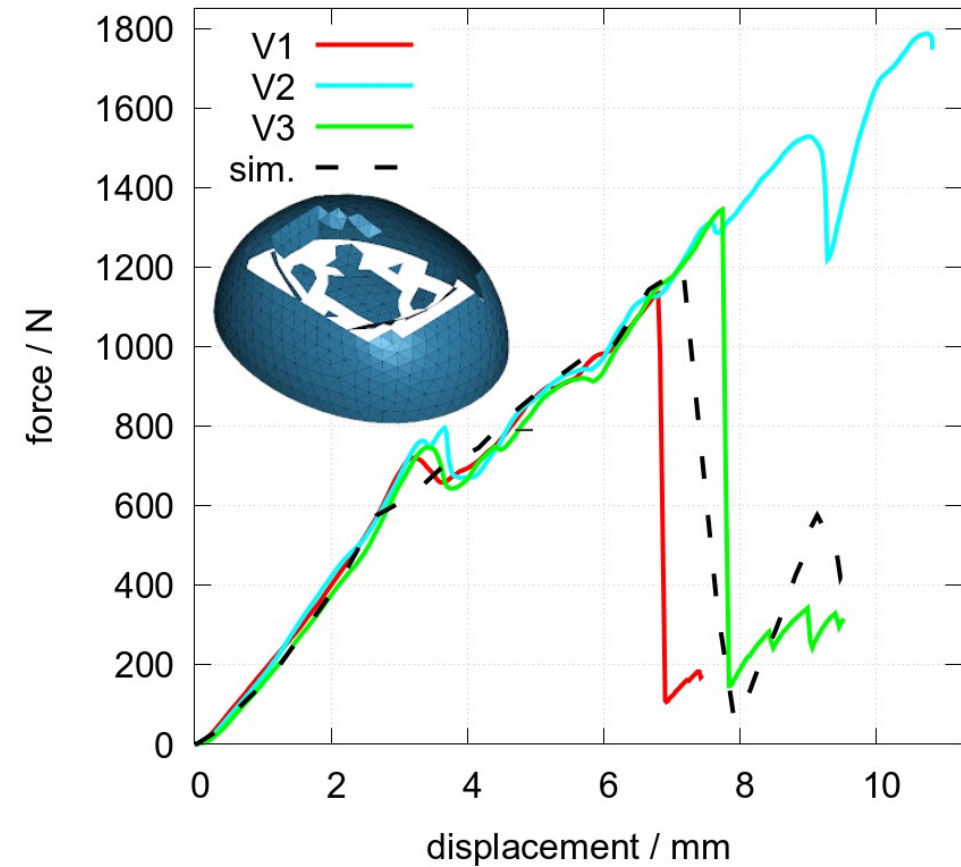
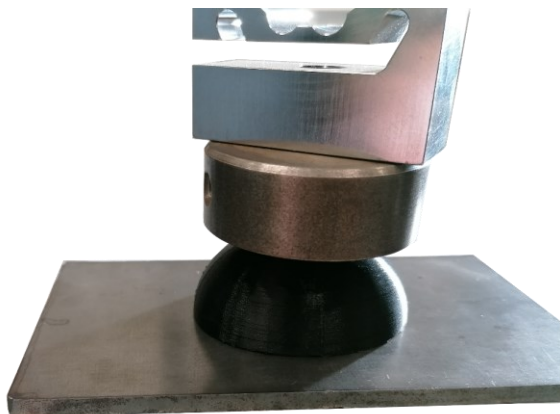


# Validation ABS

\*MAT\_ELASTIC + \*MAT\_ADD\_EROSION

## Validation Compression Test

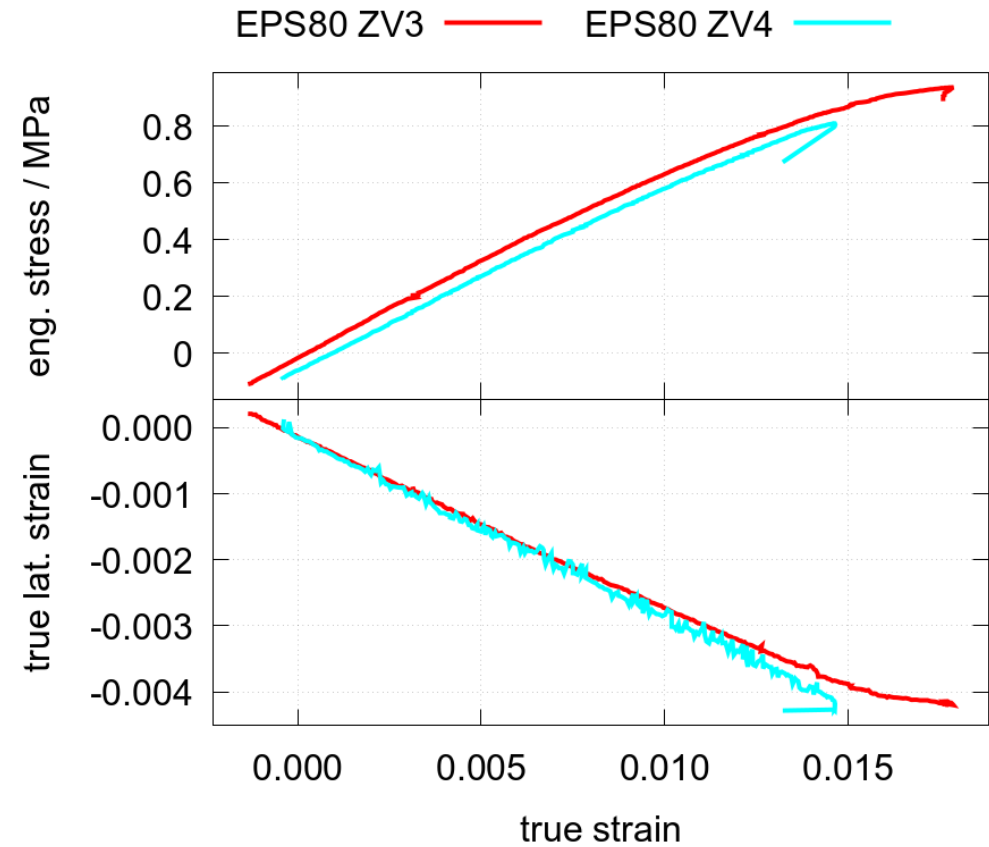
- FDM half-shell
- Specimen size: 60 x 50 x 25 mm
- 0.5 mm/s



# Expanded Polystyrene (EPS)

## Tensile Test

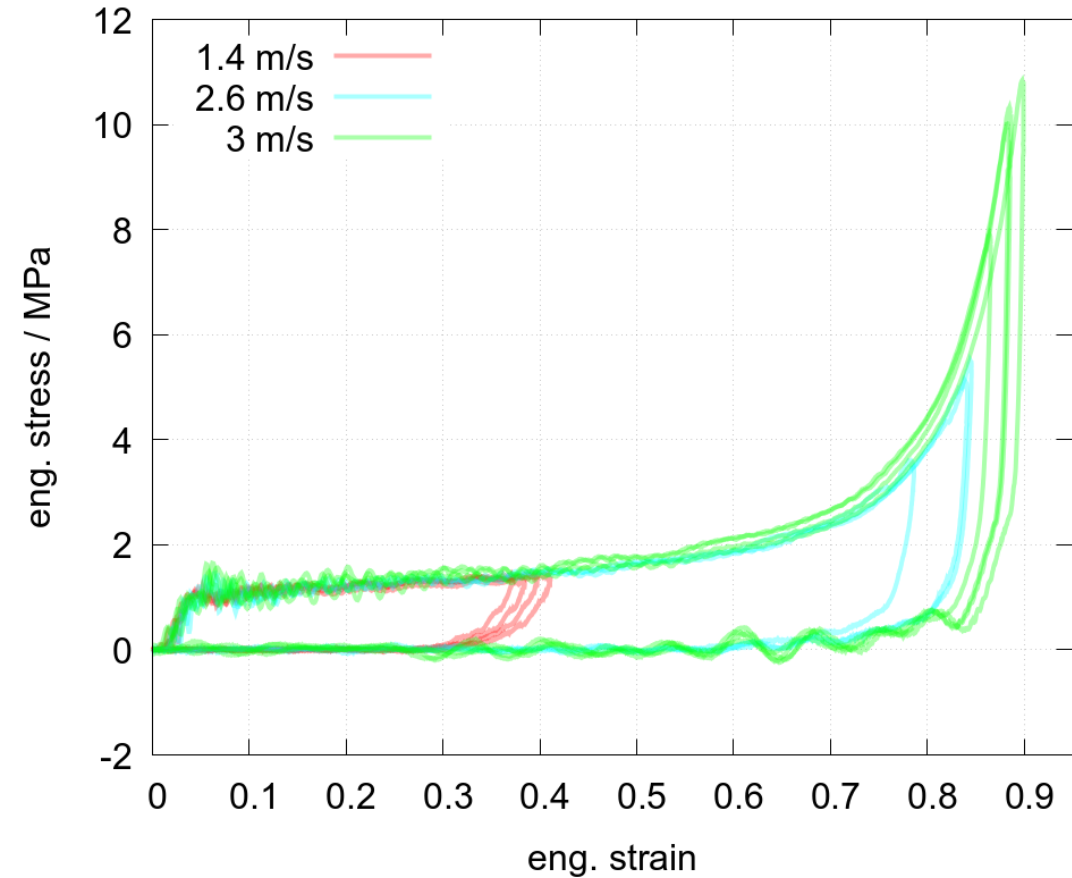
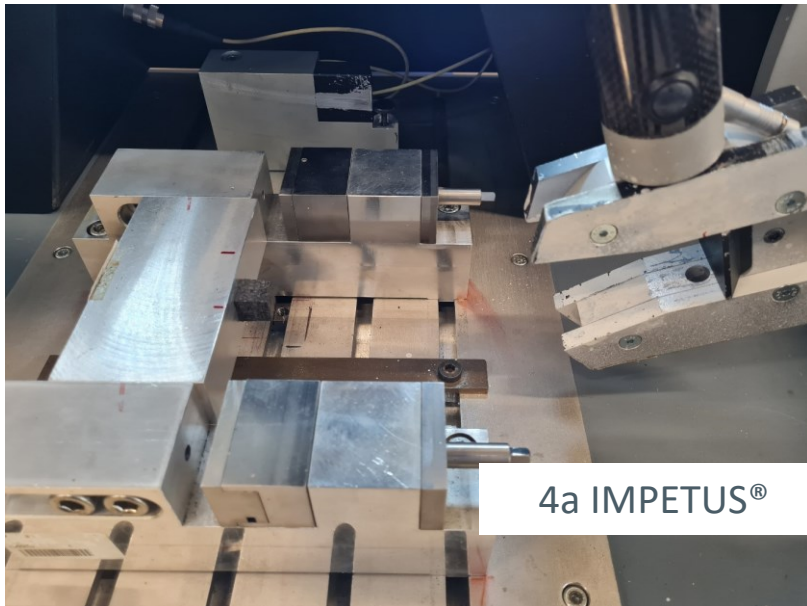
- BZ specimen geometry,  $t = 15 \text{ mm}$
- $0.5 \text{ mm/min}$



# Expanded Polystyrene (EPS)

## Compression Test

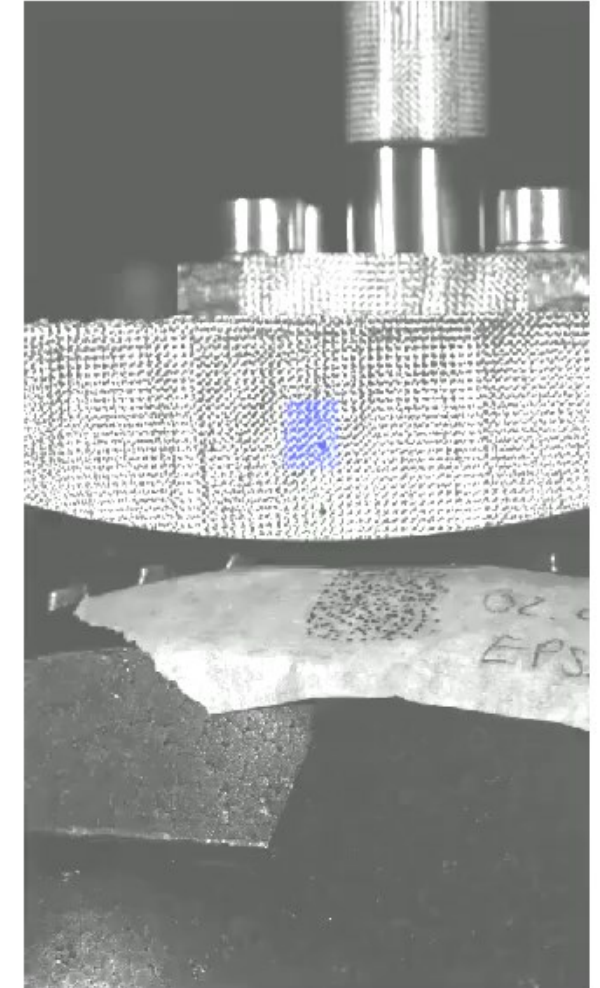
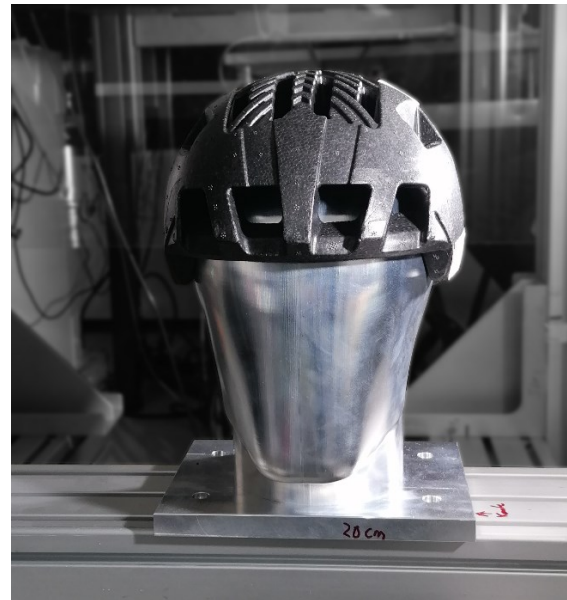
- Specimen size: 15 x 15 x 15 mm
- 1.4, 2.6 and 3 m/s



\*MAT\_SAMP-1

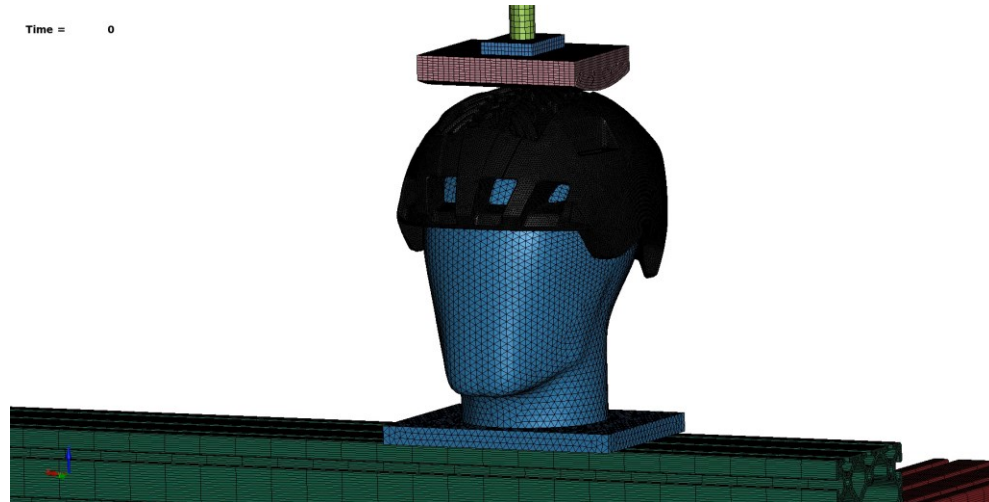
## Validation Drop Tower Test

- Instron Ceast 9350 + Highspeed VIC DIC
- 2.0 m/s + 9.3 kg
- Aluminum dummy head form

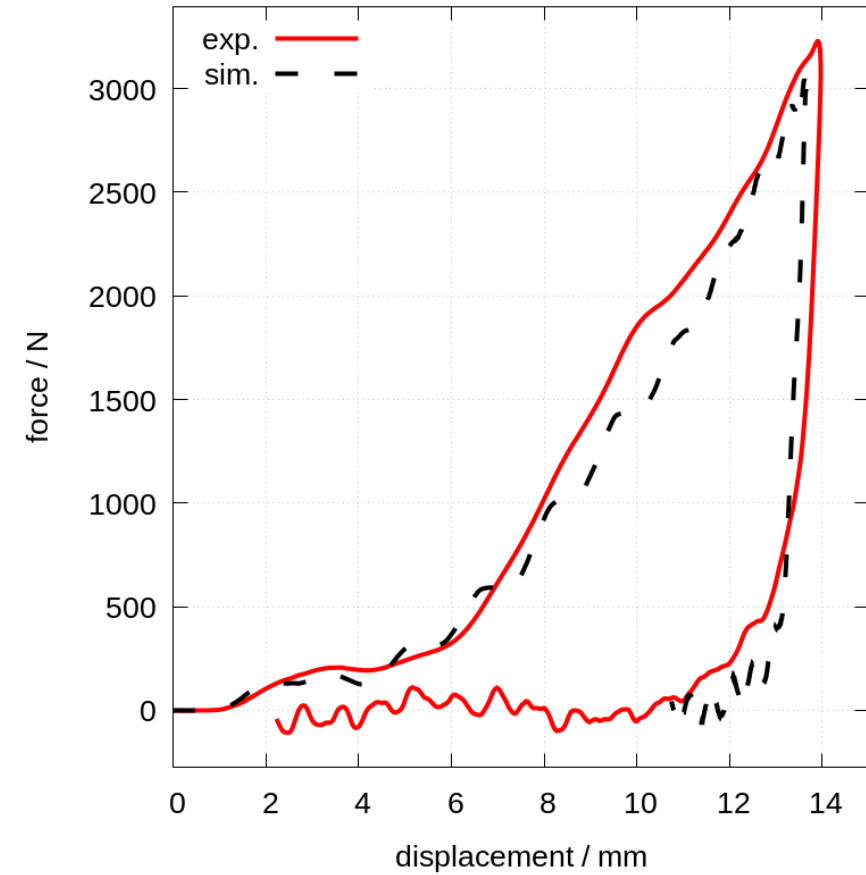
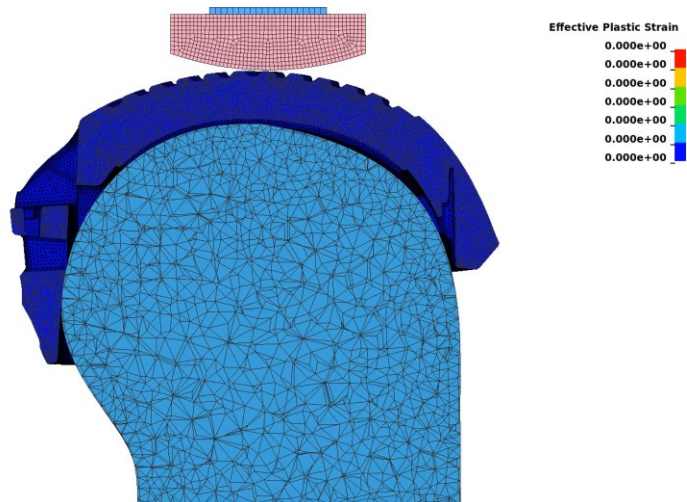




# Validation EPS

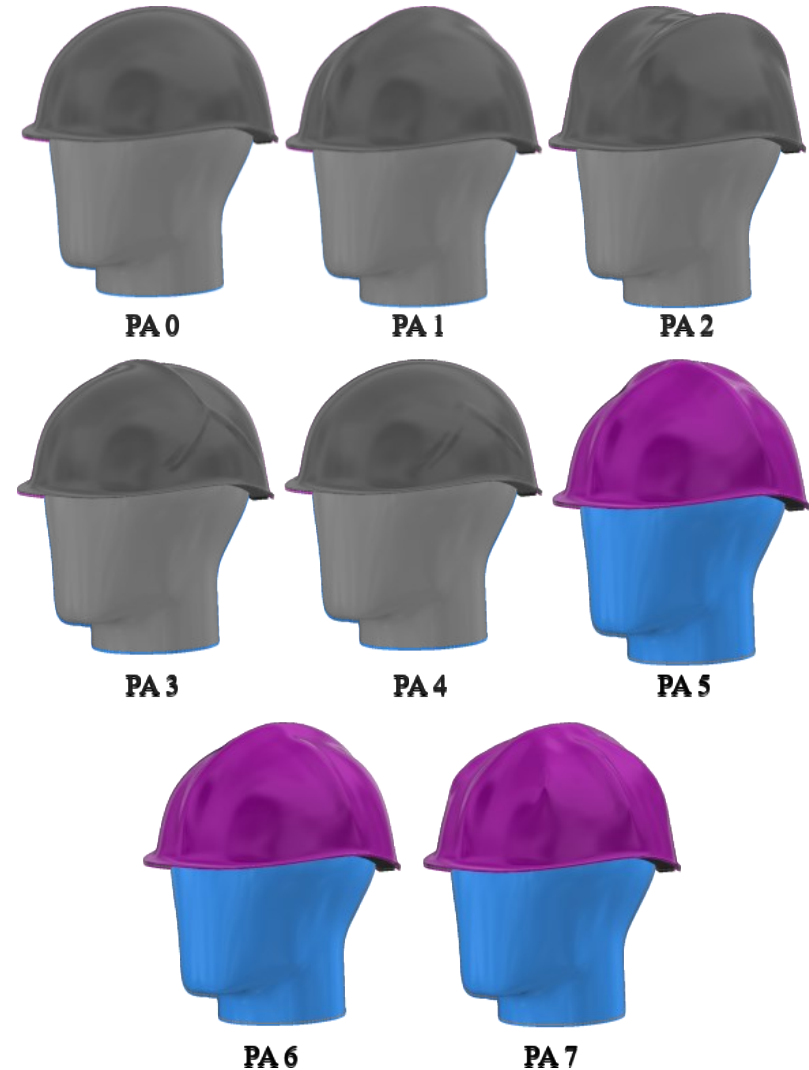
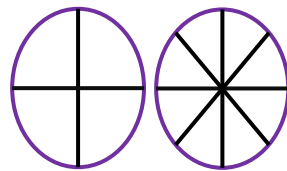


Time = 0  
section min = 0, near node# 1004371  
section max = 0, near node# 1004371



## Helmet Designs

- Base design
  - “Common” designs
- Biological inspired designs
  - Insect head capsule
- Combination
  - Cross and star shaped

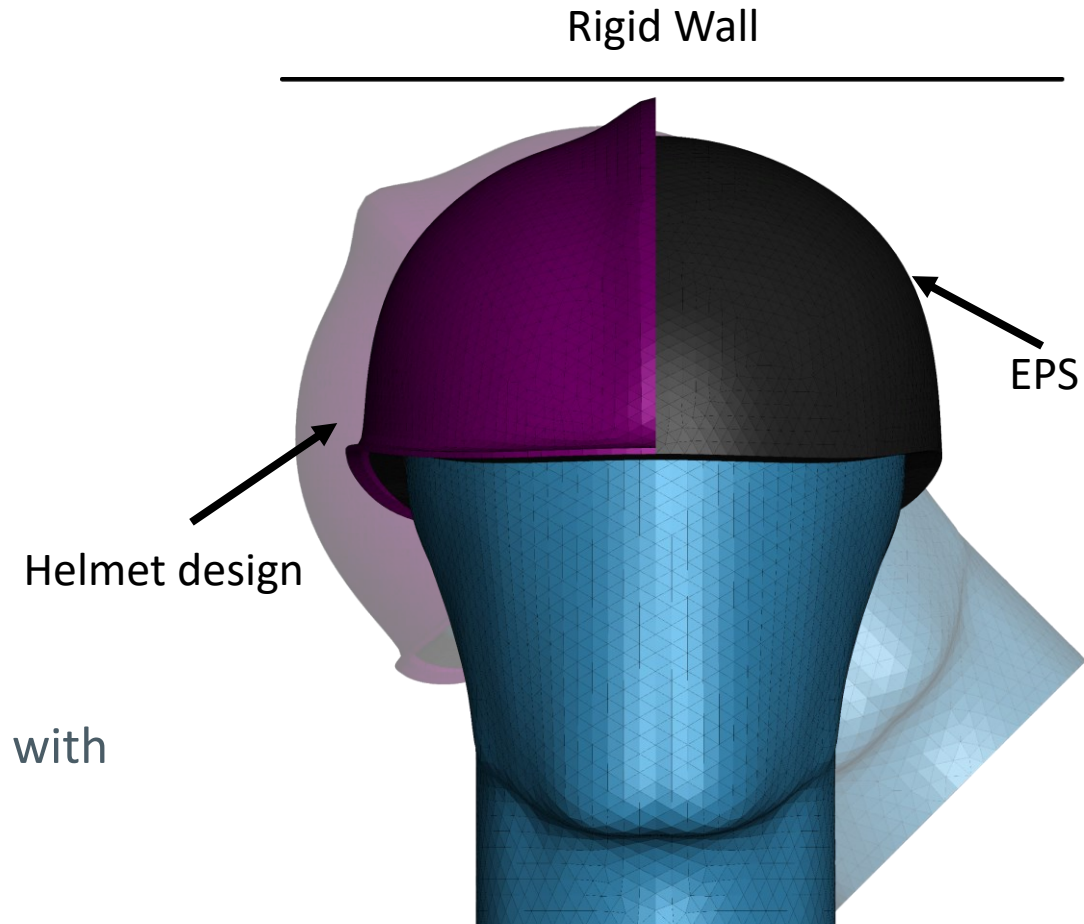


## Loadcase

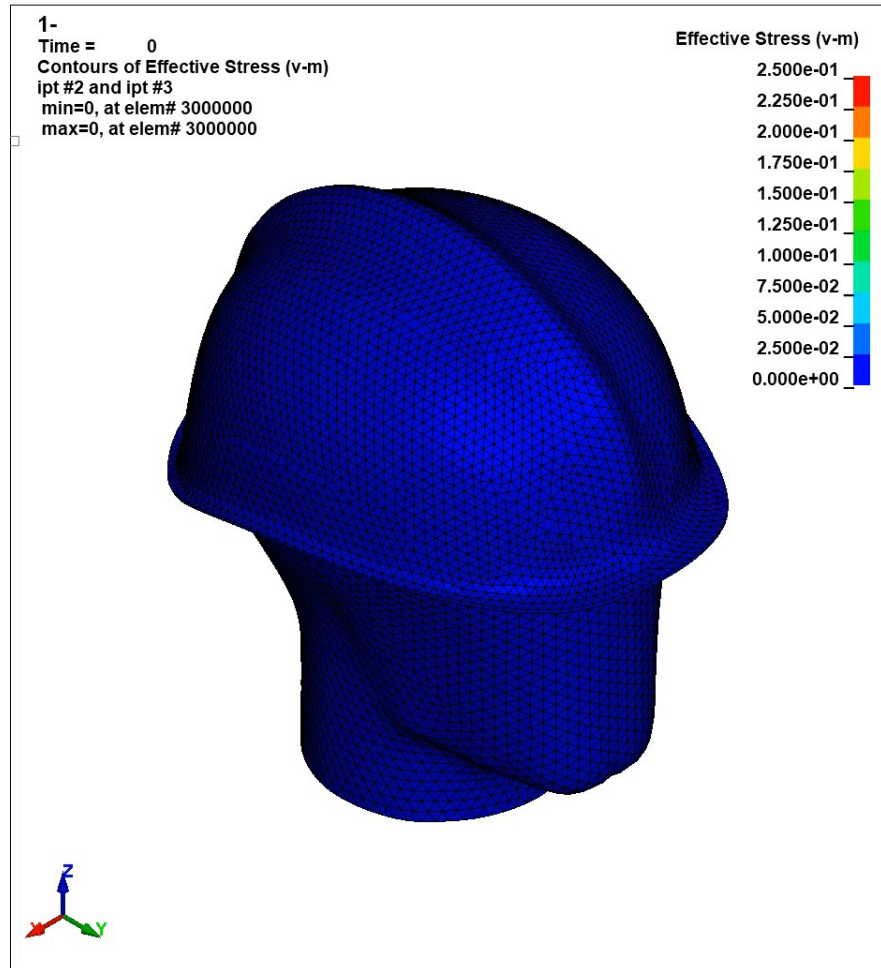
- 45° and 90°
- 5.4 m/s,  $m_{\text{head}} = 5 \text{ kg}$

## Simulation model

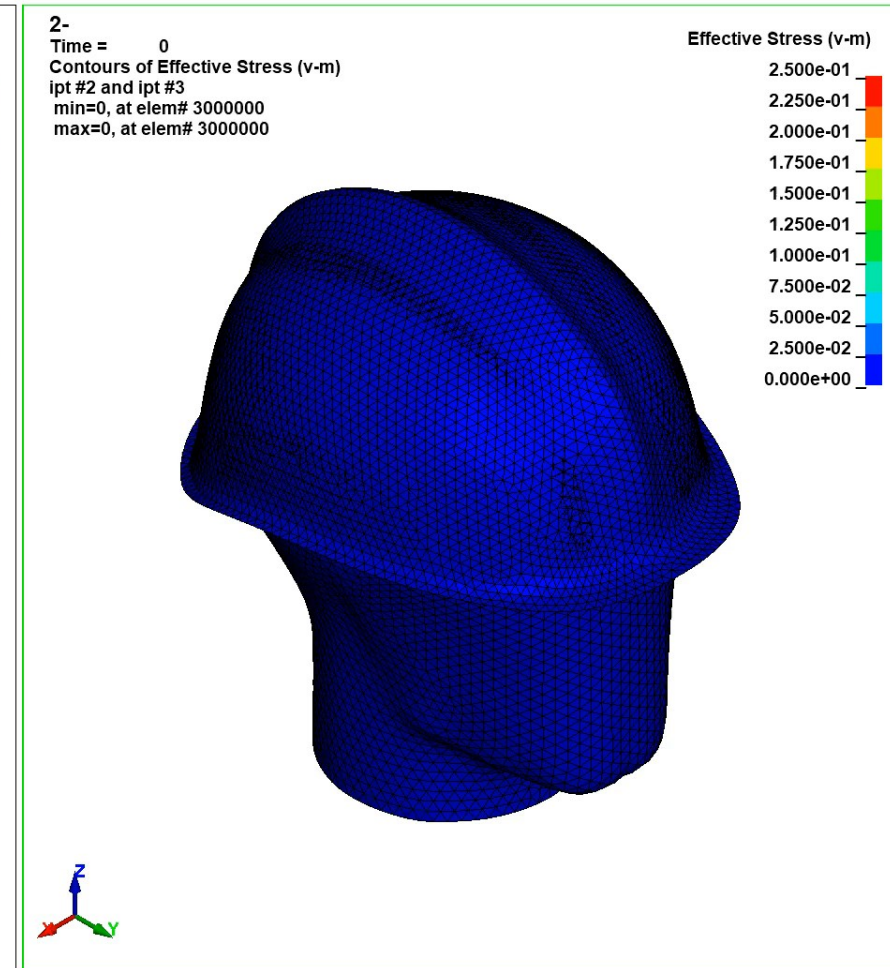
- Shell elements,  $t = 2 \text{ mm}$ , ELFORM 2
- Solid elements, ELFORM 10
- Automatic surface to surface mortar contact with SOFT=1 and IGAP=10



ABS: \*MAT\_ELASTIC



ABS: \*MAT\_ELASTIC + \*MAT\_ADD\_EROSION



## Results

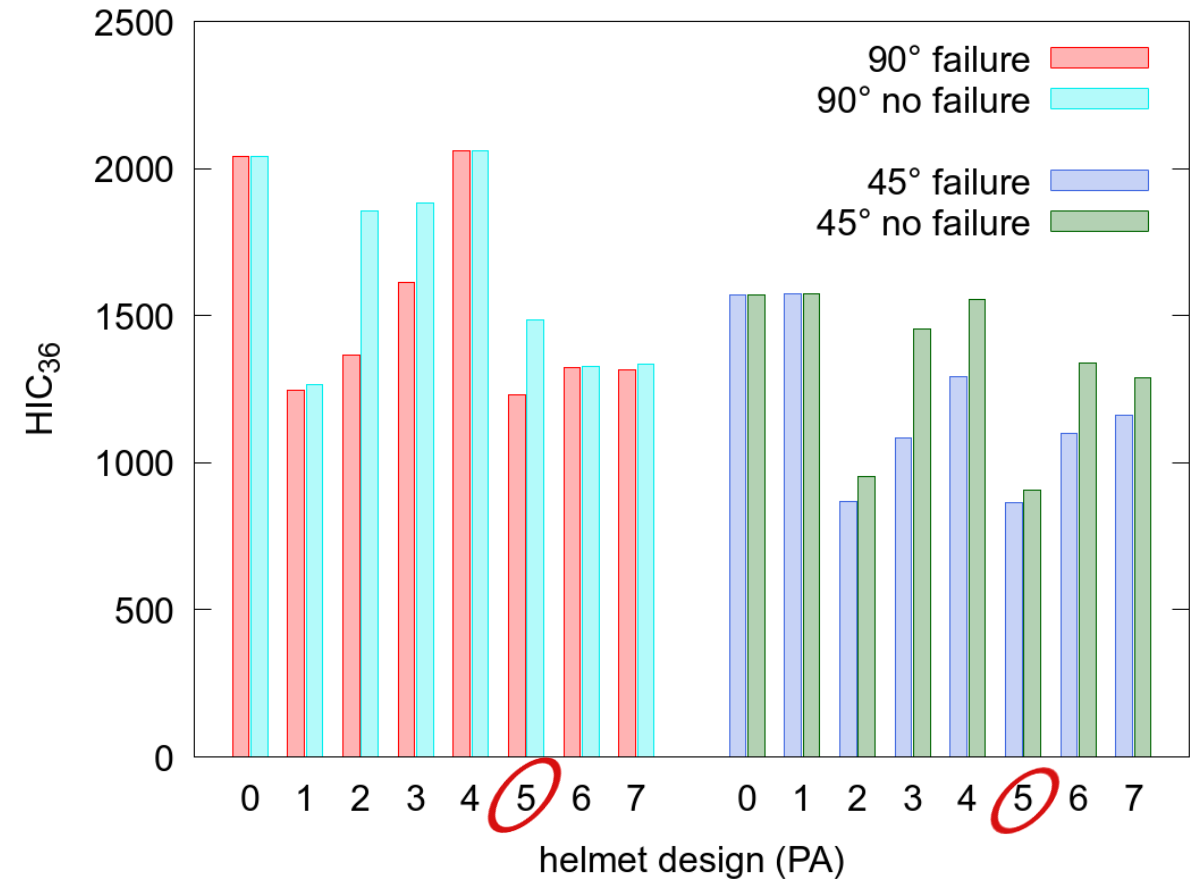
- Head injury criterion

- $HIC = \left[ \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} (t_2 - t_1)$

- ECE 22.06 motorcycle helmet

- $\leq 1300 - 2400$

→ PA 5 most promising



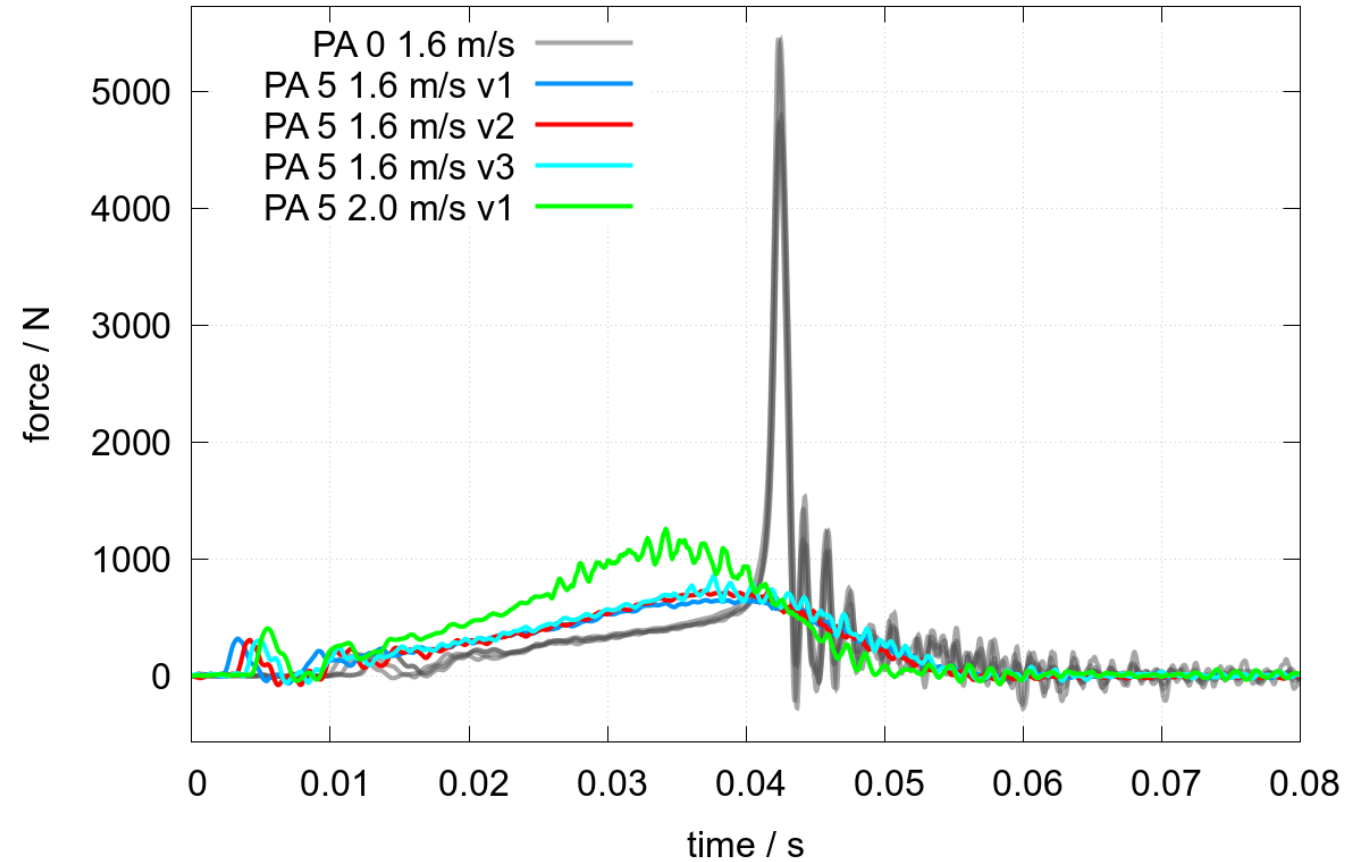
## Validation Drop Tower Test

- 1.6 and 2 m/s + 9.3 kg
- Same damping inlay

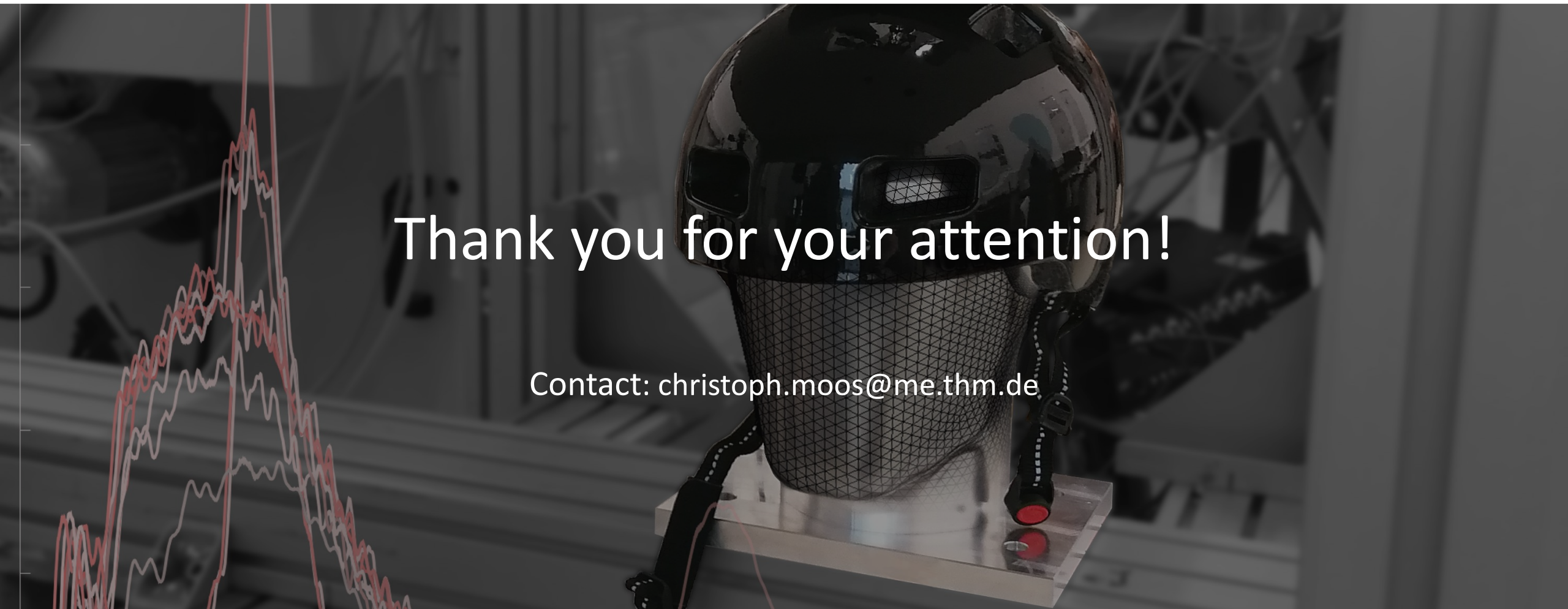


PA 0

PA 5



- Inspiration from biological models leads to optimized helmet structure
  - Characterization of relevant materials results in reliable FEM predictions
  - Rapid prototyping confirmed structural improvements in experiments
- FEM + FDM allows for fast development cycles to approach optimized helmet structures



Thank you for your attention!

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We acknowledge financial support within the BMBF program “Biologisierung der Technik” for the project “BioDASH–Bionisch Dämpfender Automatik-Schutzhelm”.



Bundesministerium  
für Bildung  
und Forschung