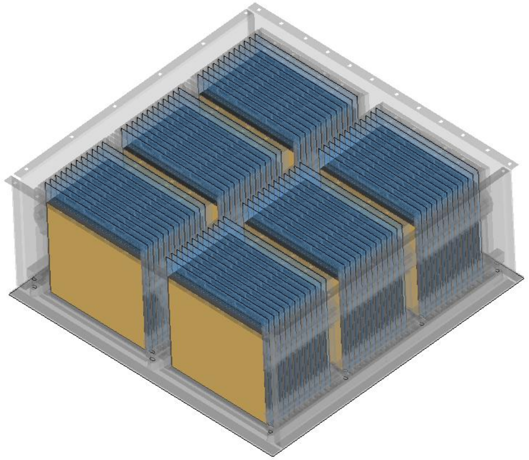


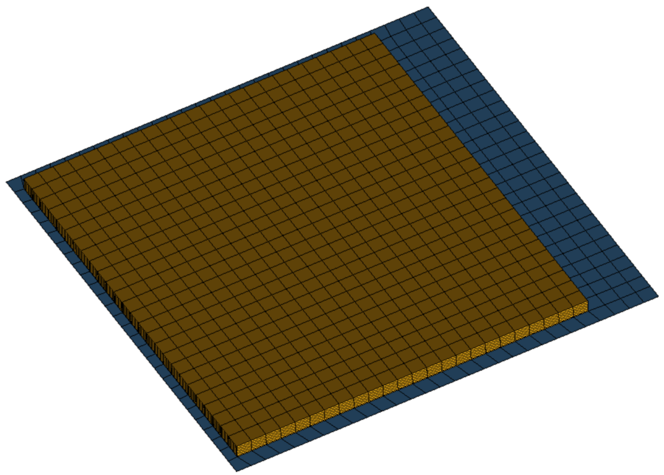
14. deutsches LS-DYNA Forum 2016

Integration of Single Cells of Lithium Ion Traction Battery in Crash Simulation

Bamberg, 10. October 2016

Dipl.-Ing. Michael Funcke

Forschungsgesellschaft Kraftfahrwesen Aachen mbH



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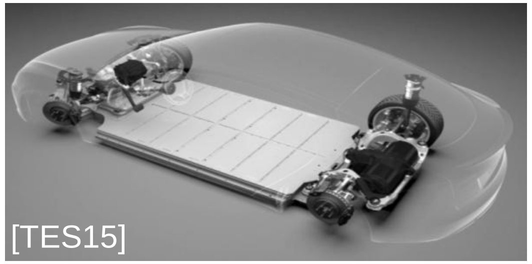
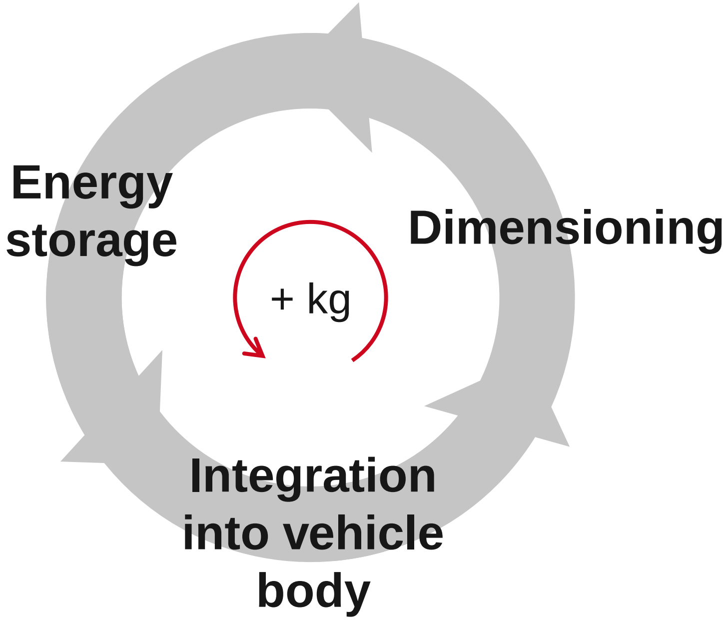
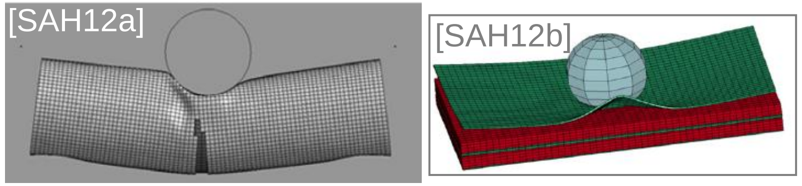
Motivation



- Low energy density of Lithium-ion cells (compared to conv. fuels)

→ Heavy storage systems



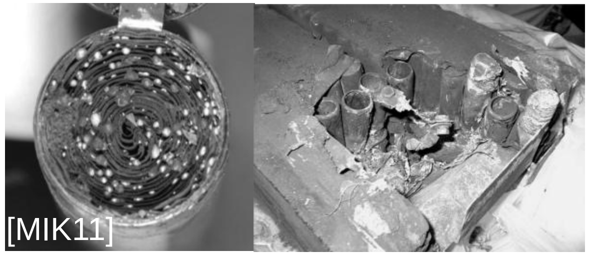


- If single cells are not part of crash simulations

→ Damage of cells not tracked

→ Manufacturers use conservative simulation approaches

→ Oversizing



- Public interest in safety of electric vehicles
- Potential hazard (e.g. thermal runaway)

→ More weight through crash-proof battery integration

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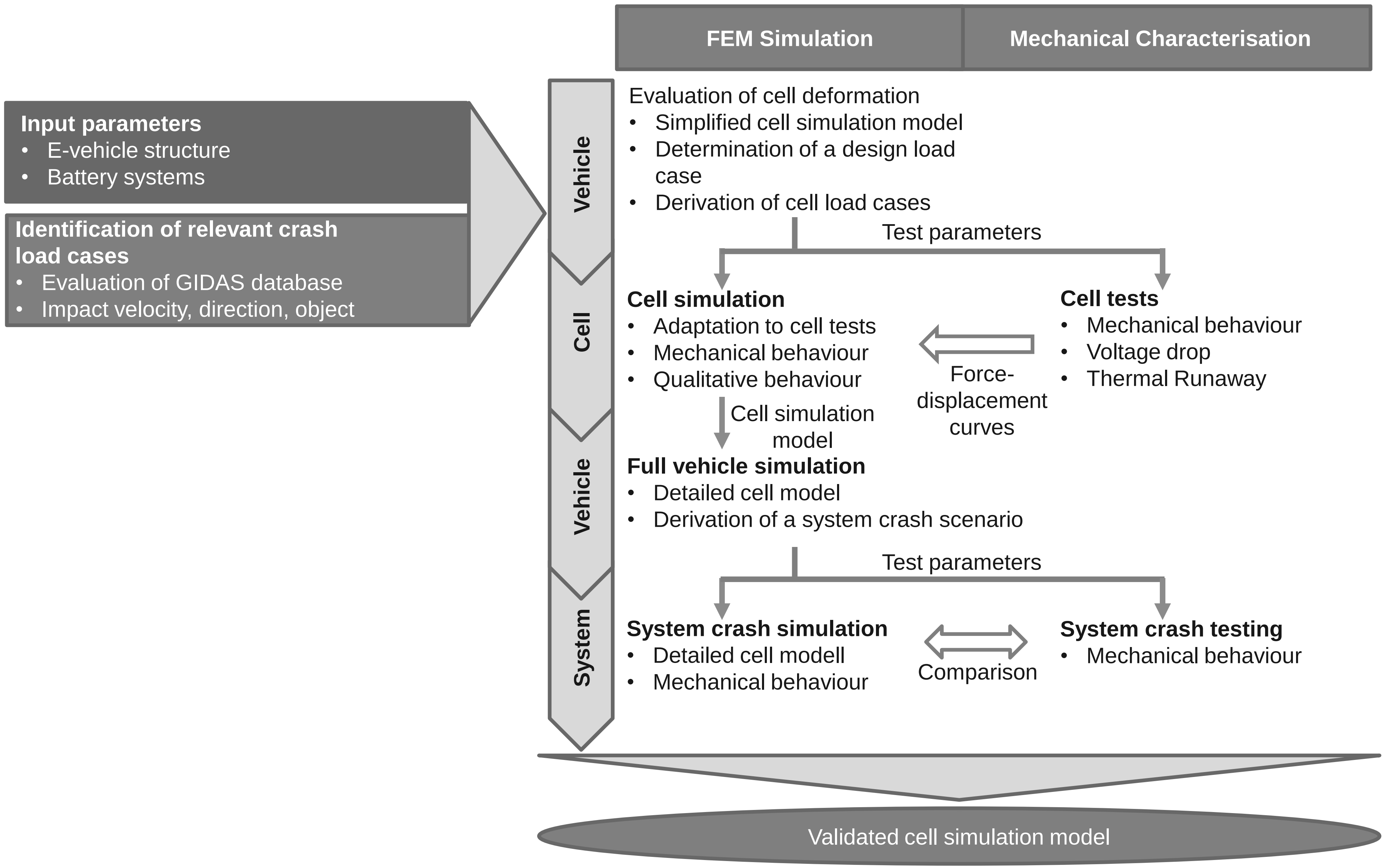
Research Approach and Methodology



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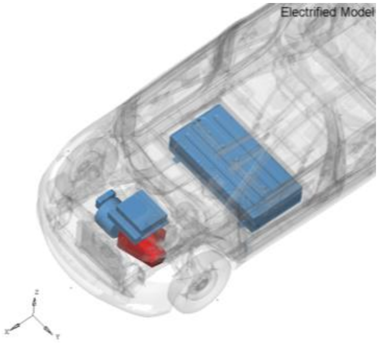
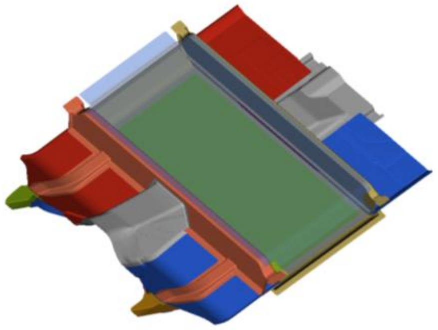
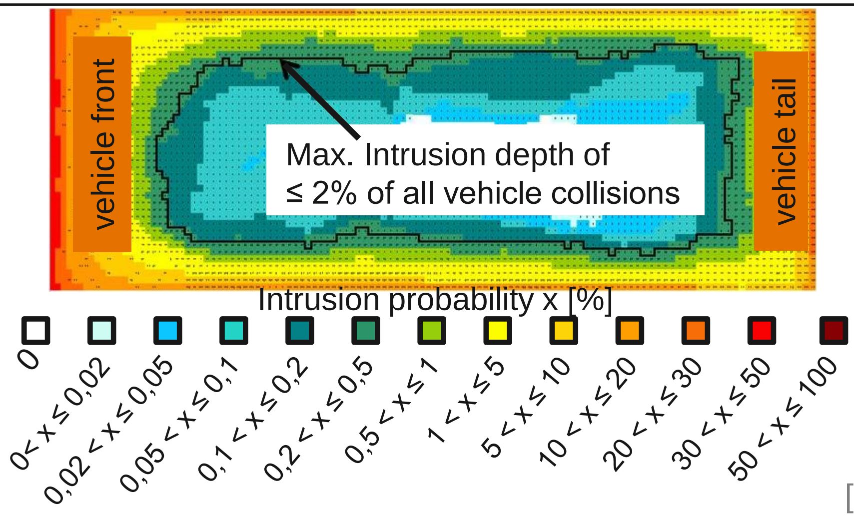
Input Parameters

E-vehicle structure
Toyota Yaris





Crash data



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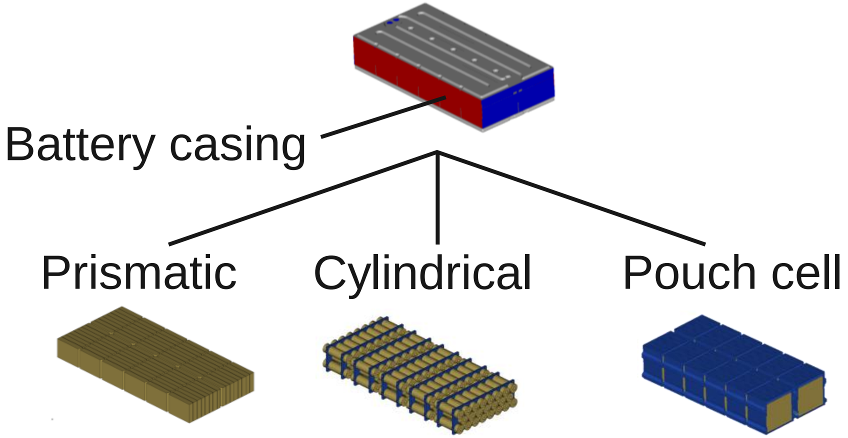
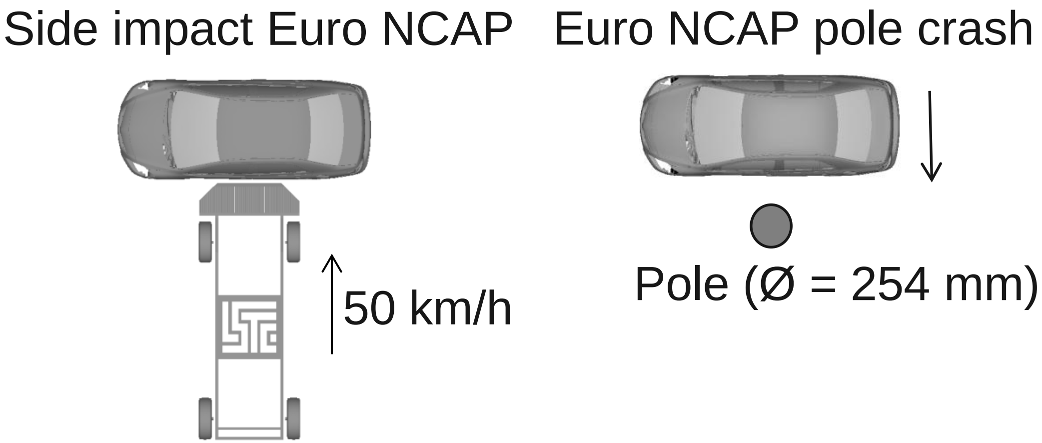
Battery structure



Load cases



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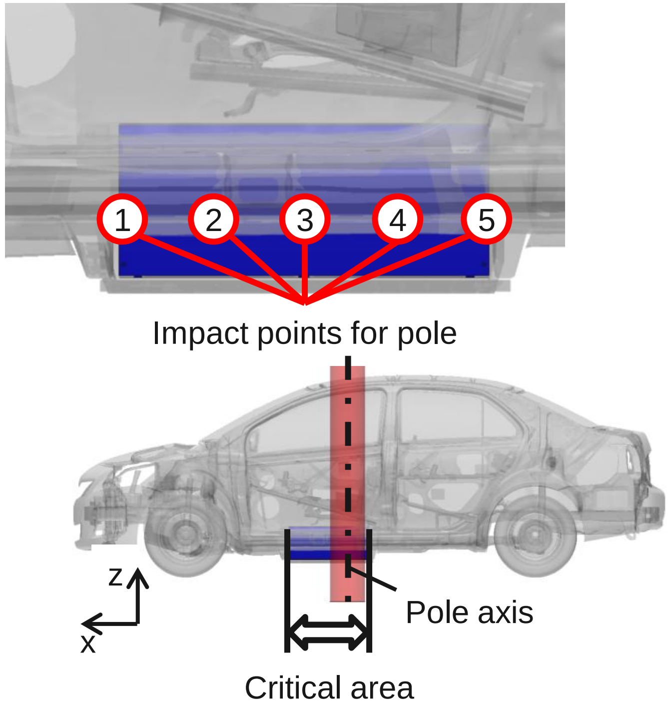
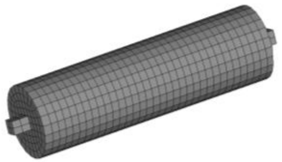
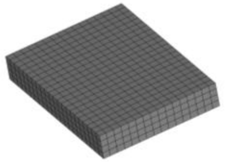
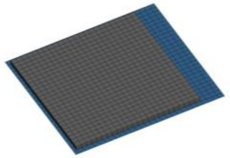
Evaluation of energy storage deformation

Vehicle | Cell | Vehicle | System

Simulation | Testing

- Set up of simulation models for the energy storages and integration into the overall vehicle model
- Use of simplified cell models:
  - Linear-elastic material behaviour
  - Representing outer geometry
- Simulation of aforementioned load cases
  - Deformation of vehicle body and energy storage within pole impact very localised
  - → Variation of pole position
- Evaluation of energy storage deformation
  - Low / no deformation at barrier impact
  - → Pole impact is the more critical load case
  - → Following consideration of pole impact at 50 km/h



Cylindrical cell	Prismatic cell	Pouch cell
		

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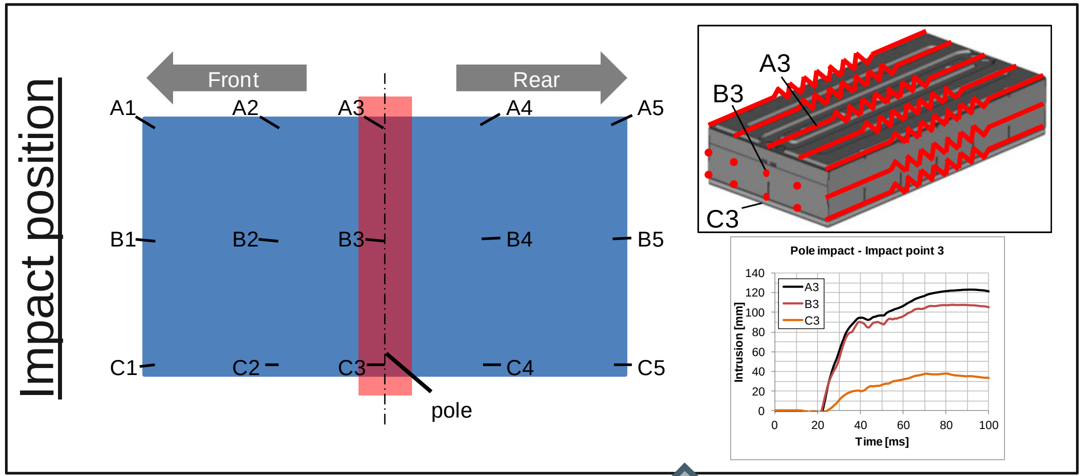
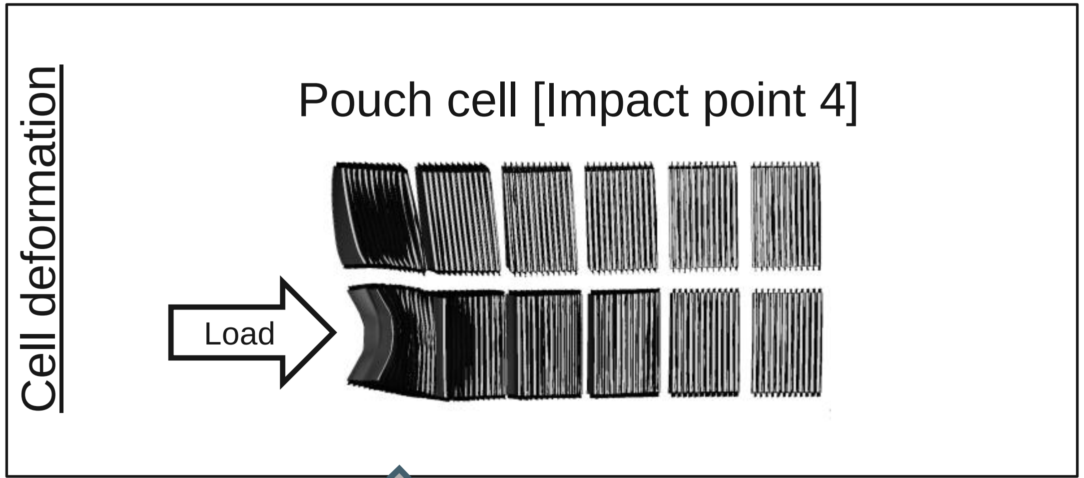
Cell selection

Vehicle
Cell
Vehicle
System

Simulation
Testing





	Cylindrical	Prismatic	Pouch cell
Deformation of energy storage housing (FE simulation)	high	low	high
Cell deformation (FE simulation)	low	low	high
Tolerance of the cell to deformation	low	low	high
Internal cell security mechanisms	available	available	unavailable
Massive cell housing / protection against sharp objects	available	available	unavailable
Potential risk of cell chemistry	medium (LiFePO4)	medium (LiFePO4)	high (NMC)

[KOR13]

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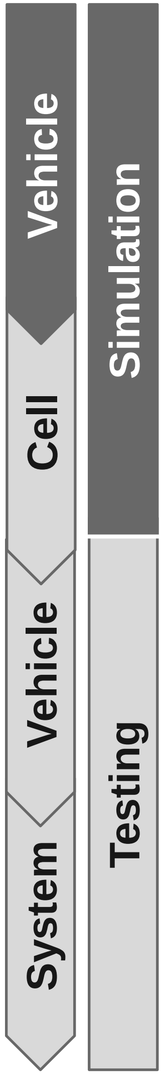
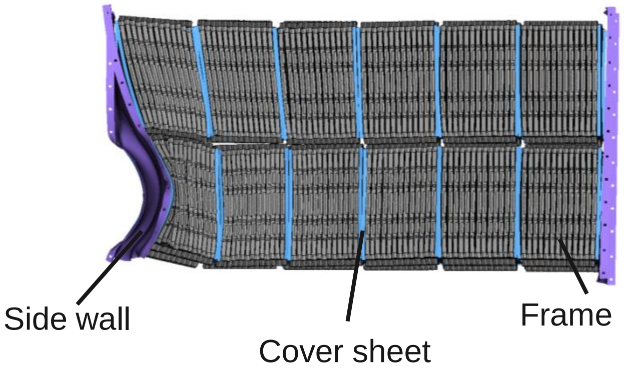
Derivation of load cases on cell level

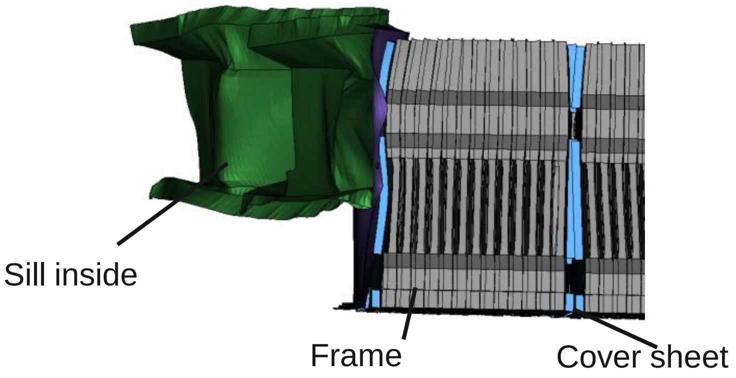


Overall load on vehicle level

Top view

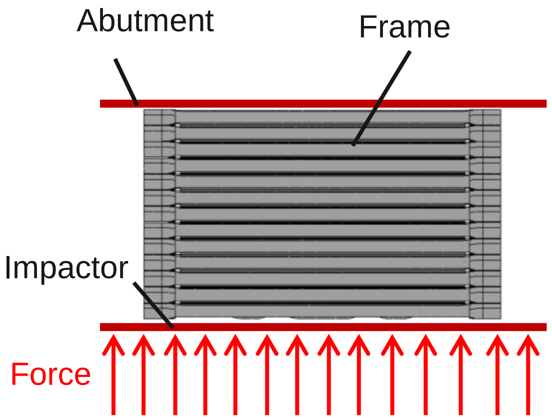


Rear view

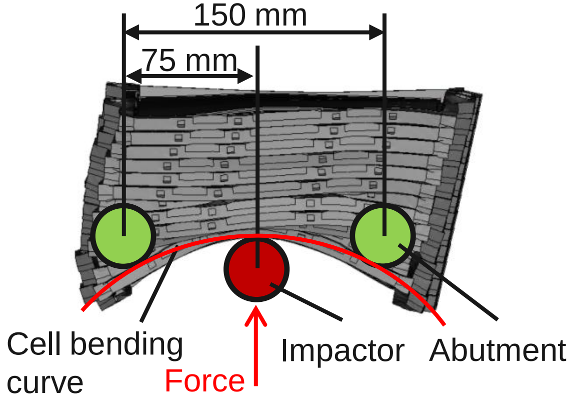


Superimposed load cases

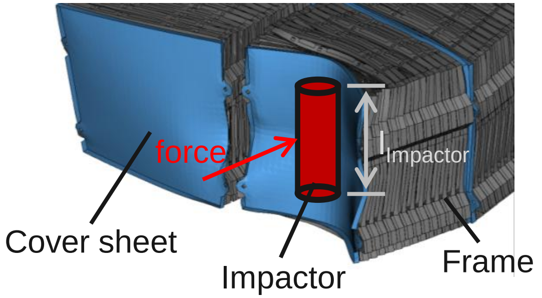
Compression



Bending



Punch through



$l_{Impactor\ 1}$ = 100 mm $l_{Impactor\ 2}$ = 170 mm

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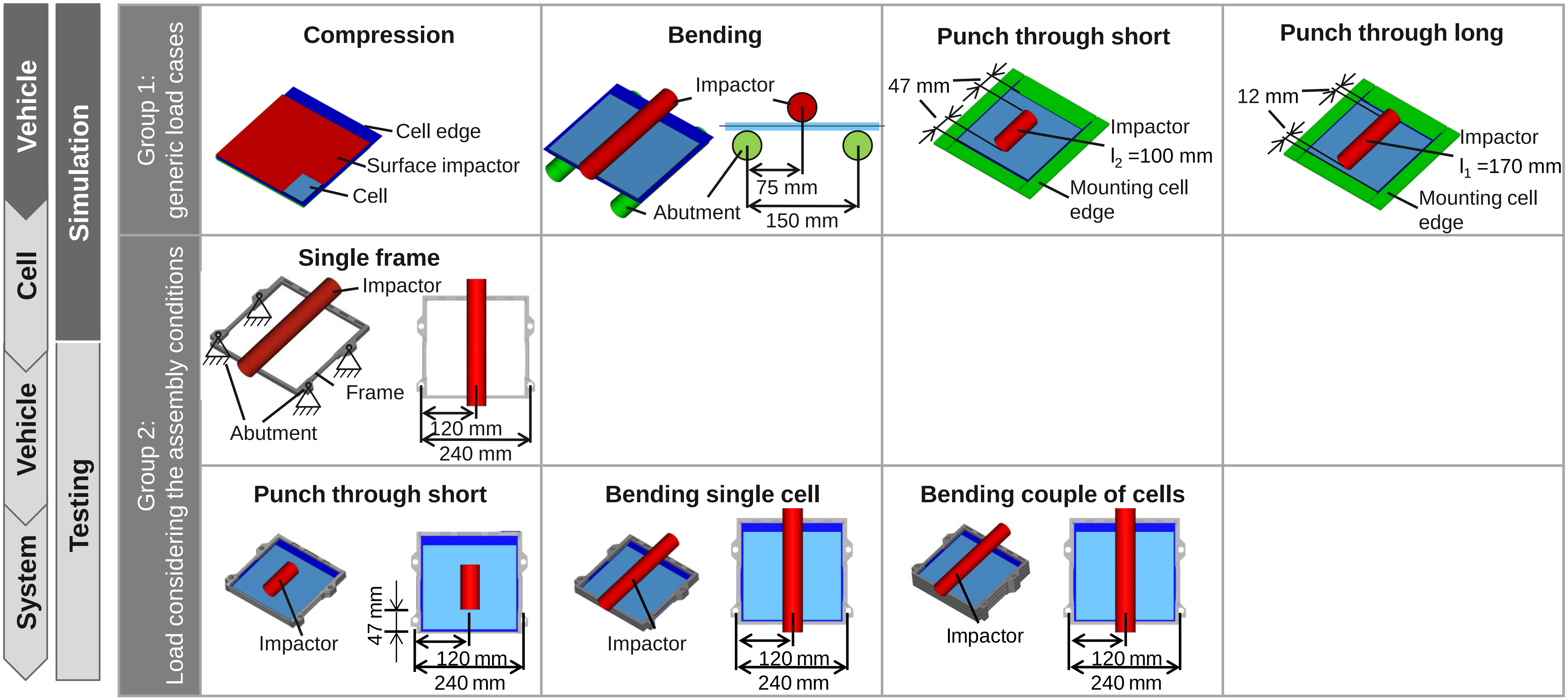
Derivation of load cases on cell level



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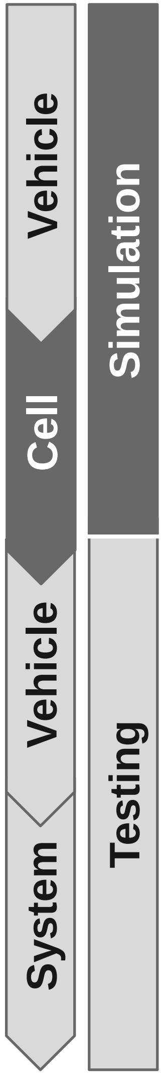
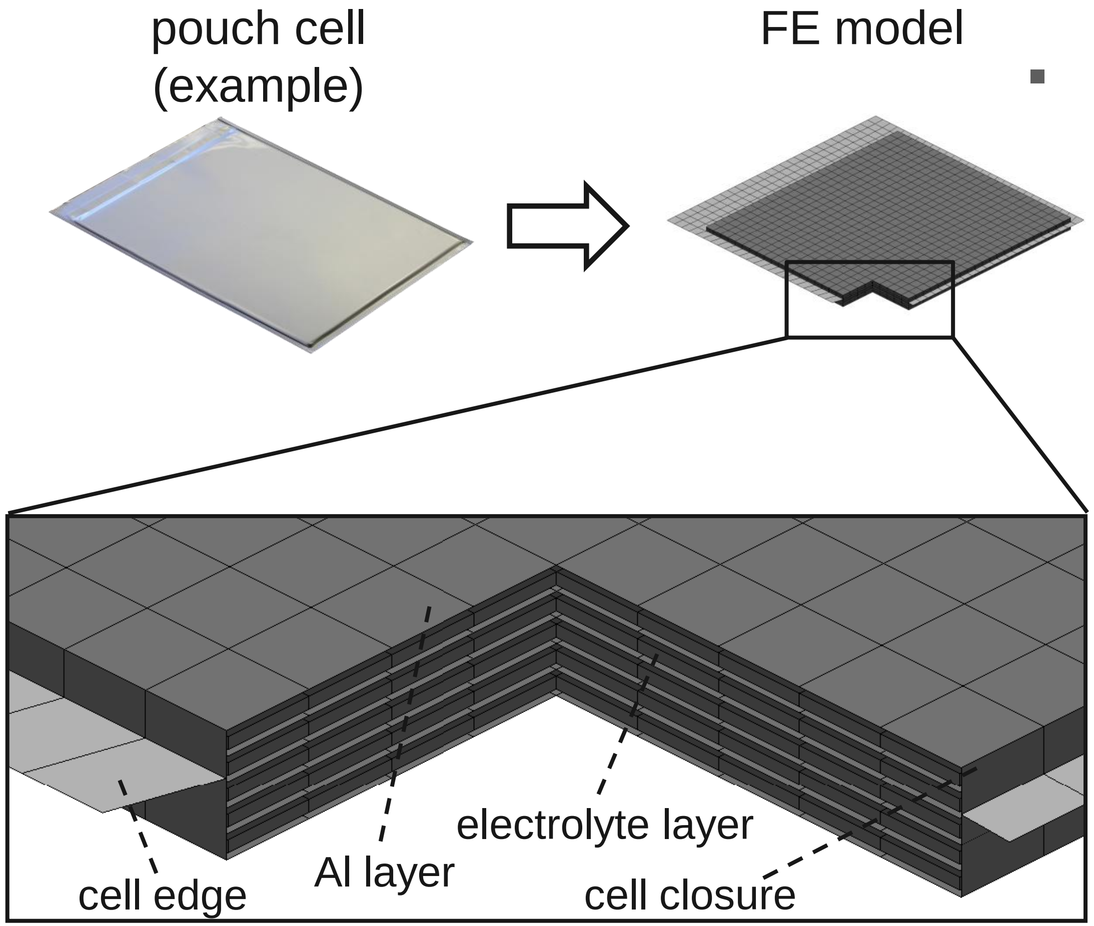
Set-up of cell simulation model





- Simulation approach:
  - Five layers of solid elements representing the electrolyte
  - Six layers of shell elements representing the electrodes
    - No connection between solid and shell elements
    - Slipping between layers possible
  - Cell edge representing the surrounding clamping area
    - Connected to solid elements (tied contact)
  - Cell closure connecting the outer shell layers
    - Failure (Mat_add_erosion)
    - Part_composite (three layers)
  - Time step equivalent to full vehicle simulation

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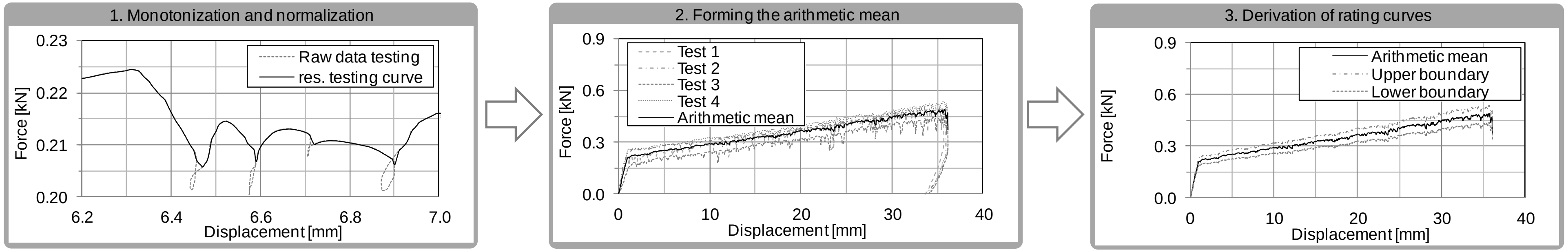
Built-up of cell simulation model

Vehicle
Cell
Vehicle
System

Simulation
Testing

- Execution of cell tests
- Derivation of target range for the simulation curves



- Sensitivity analysis to determine the parameter influences of the simulation model

		Influence on force-displacement-curve of the load case			
Component	Parameter	Uniaxial crushing	Three point bending	Punch through short	Punch through long
Solid element layer	Stress-strain curve	↑	↗	↗	↗
Interaction cell edge and clamping	Friction coefficient	–	–	↗	↗

–	Parameter n.a.
↗	Low influence
→	No influence
↑	High influence

- Successive determination of the model parameters through comparison of testing and simulation
  Uniaxial crushing → three point bending → punch through short → punch through long

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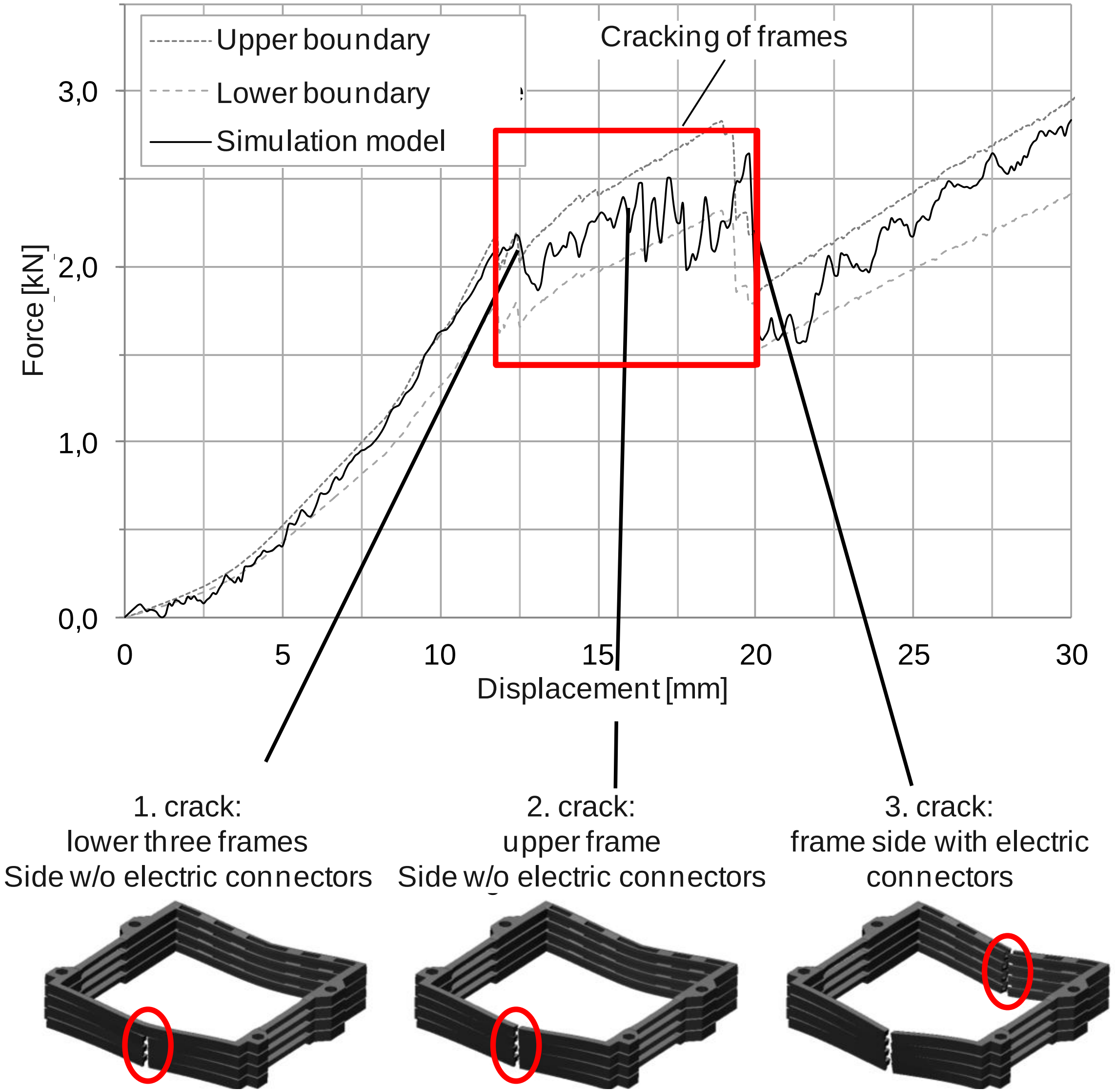
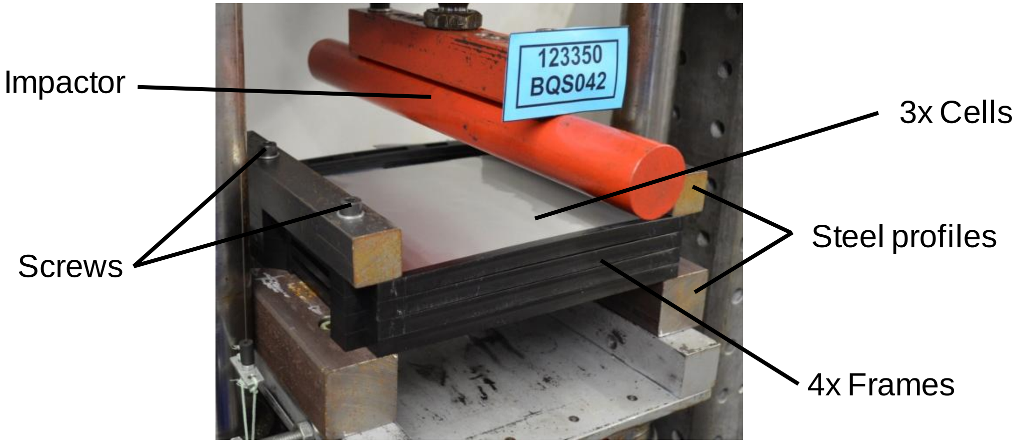
Built-up of cell simulation model



- Built-up and validation of the frame model
- Simulation of group 2 load cases

→ Cell simulation model validated for quasi-static load cases



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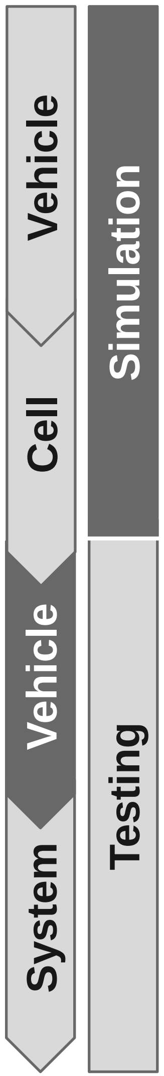
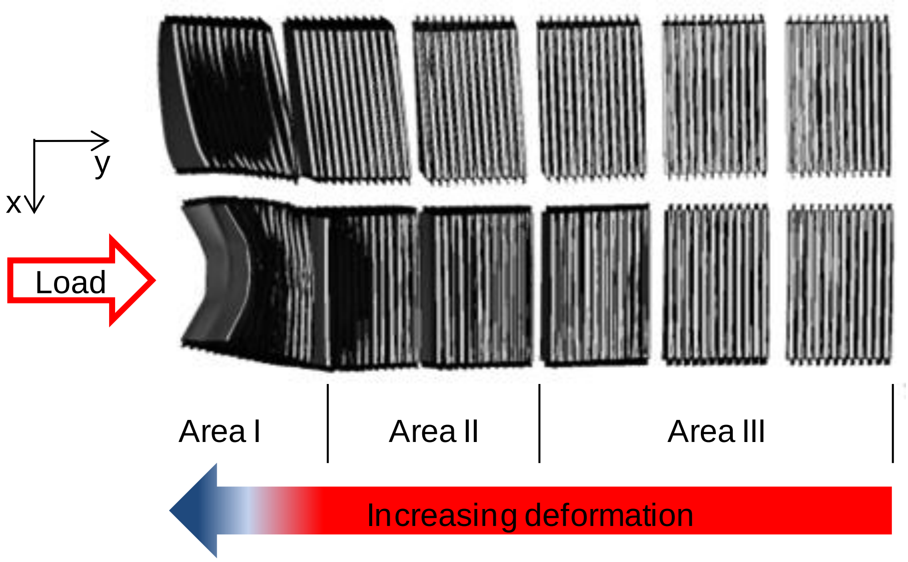
Validation of the simulation model and discussion of results



- Integration of cell model in full vehicle simulation model
- Examination of the cell deformation within the load case pole impact



- High deformation within Area I
- Stiffness of area II influences deformation within area I
- Deformation within area III very low

→ **Validation on system or vehicle level necessary**

- No vehicle available for crash testing

→ **Derivation of a system load case, which considers the loads acting on full vehicle level**
  - → **Impactor diameter**
  - → **Impact velocity**
  - → **Absorbed kinetic energy, leading to impactor mass**

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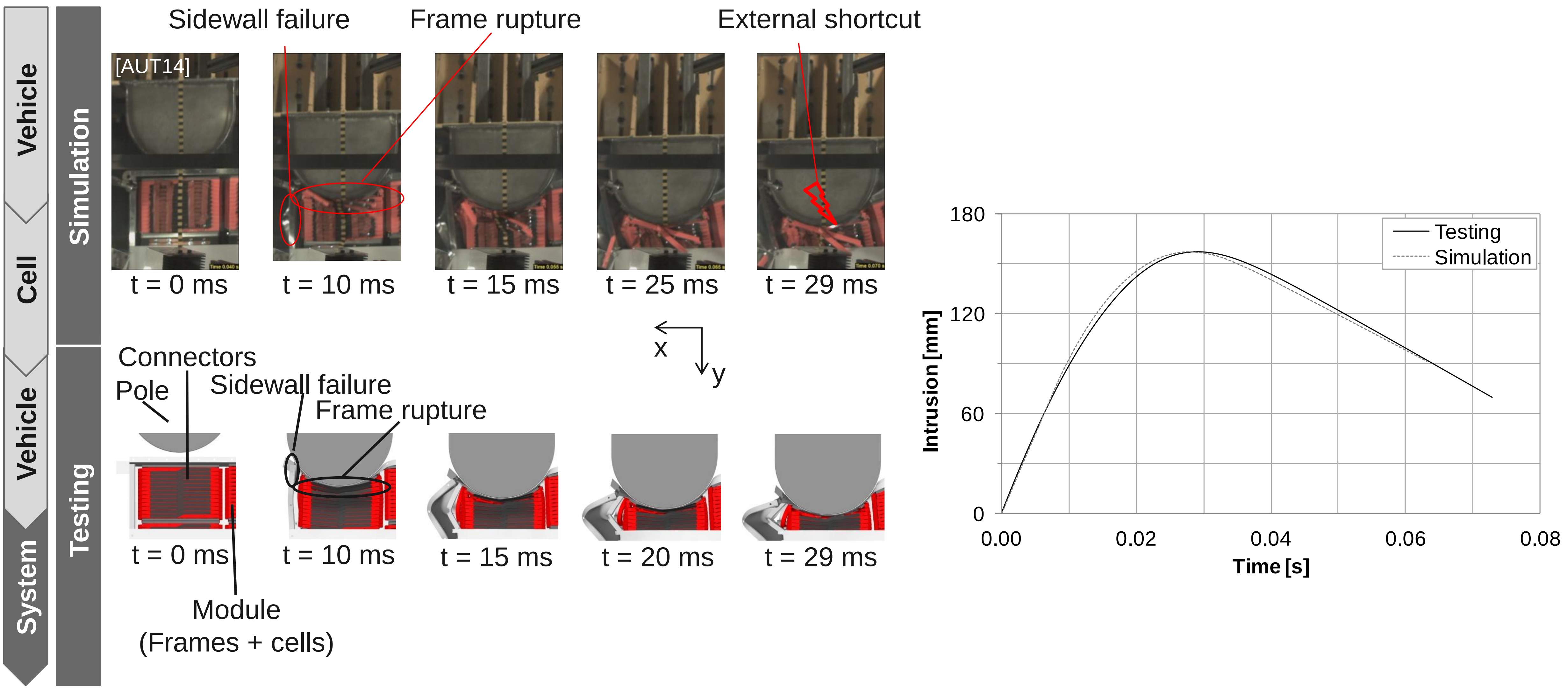
Validation of the simulation model and discussion of results



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Summary

- Within this research a simulation approach for pouch cells applicable to crash simulations on full vehicle level was investigated
- A simplified cell model was used to derive load cases on cell level from full vehicle simulations
- Test of theses load cases were carried out and the results were used for a stepwise model built-up

- Final validation by a system crash test showed a good correlation between simulation and testing

→ Generation of a cell model applicable for full vehicle simulations was successful

- As long as the mechanical cell loads correspond to those used for the built-up process the generated cell model is applicable for various storage system layouts and positions within the vehicle

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Contact

Thank you for your Attention!

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