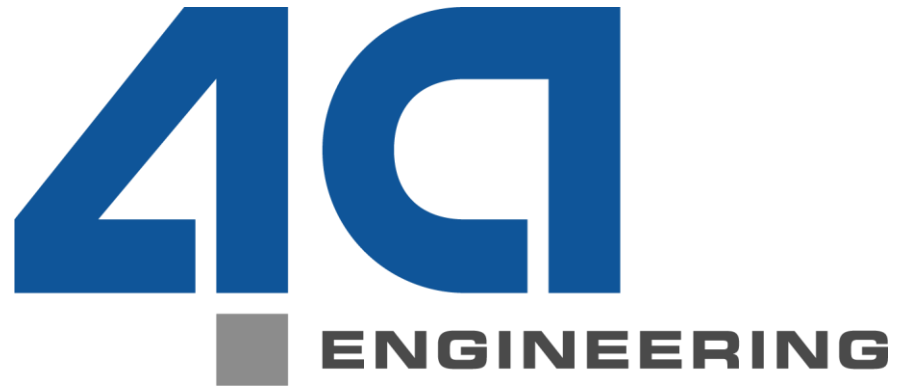


Abuse Simulation of Battery Packs based on the Testing of Single Battery Cells

Robert Kießling

Advanced Battery Power 2022



excellence in ...
plastics simulation
testing equipment
lightweight products



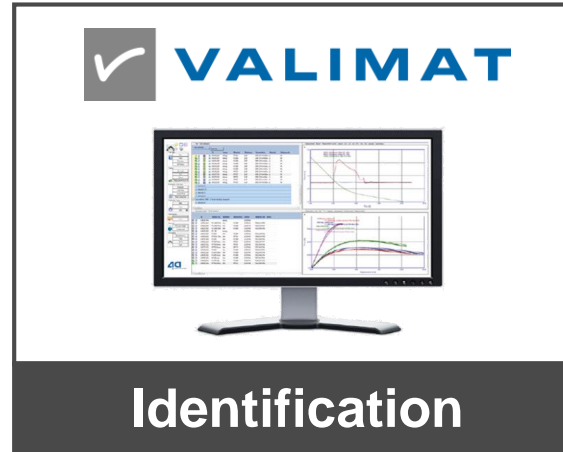
Testing and Identification



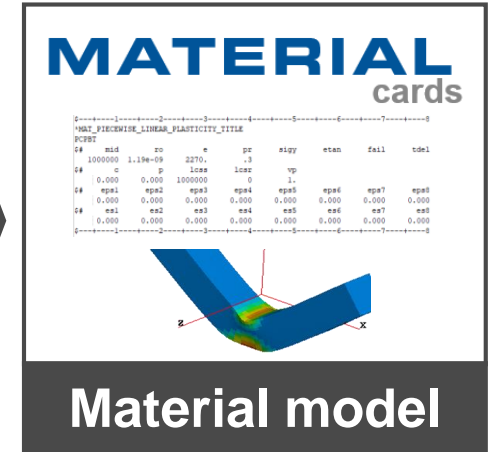
Material



Testing



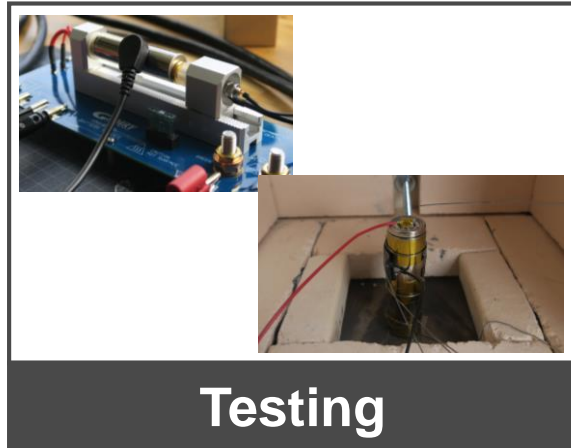
Identification



Material model



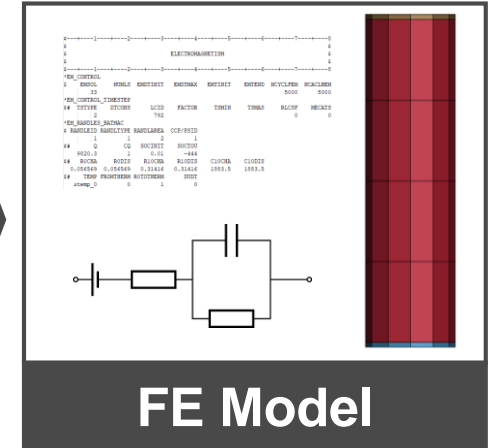
Battery Cell



Testing



Identification



FE Model



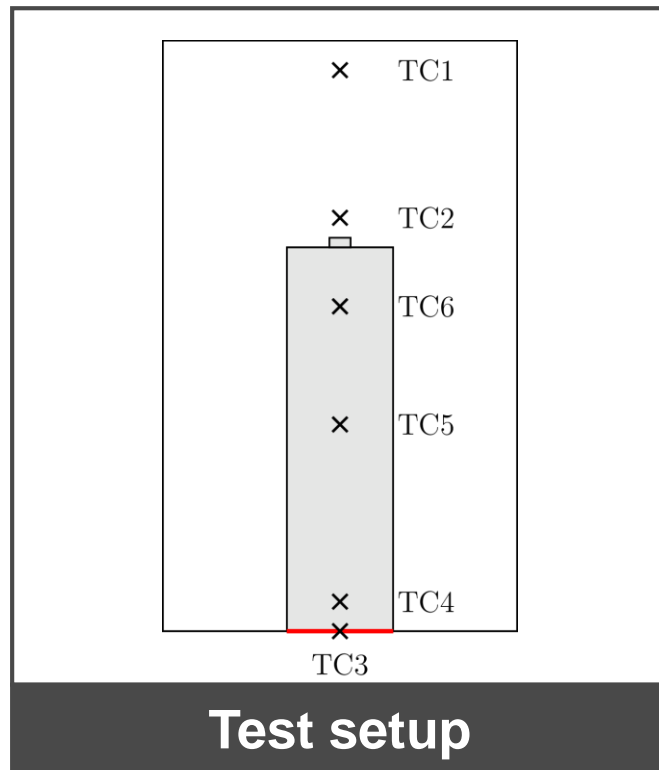
Outline

1. Abuse testing of a single cell
2. Abuse simulation of a single cell using LS Dyna
3. Integration of a single cell model in a simulation of a multi-cell mockup
4. Conclusion and outlook

Abuse testing of a single cell

Overheat test of a battery cell

- Overheating of a fully charged 18650 battery cell (Panasonic NCR18650B) at the bottom
- Measurement of the temperature at the cell as well as in the chamber with 6 thermocouples
- Measurement of the voltage

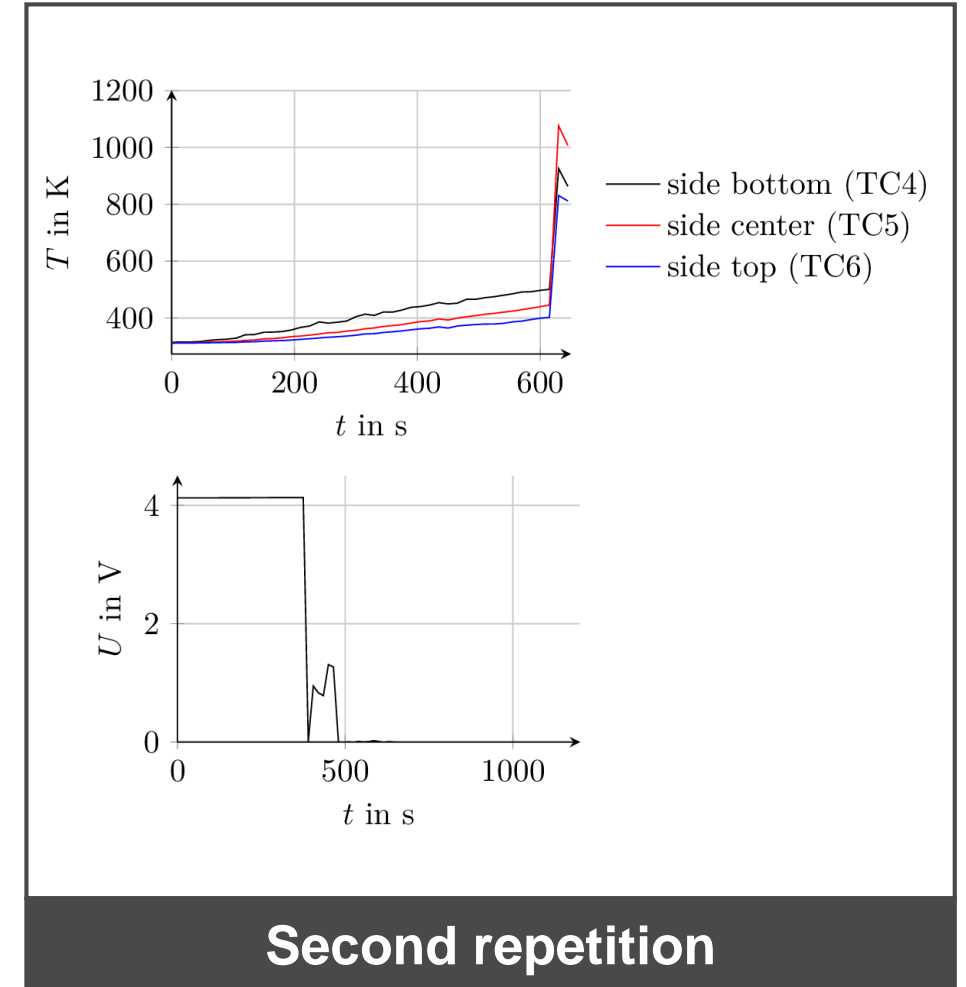
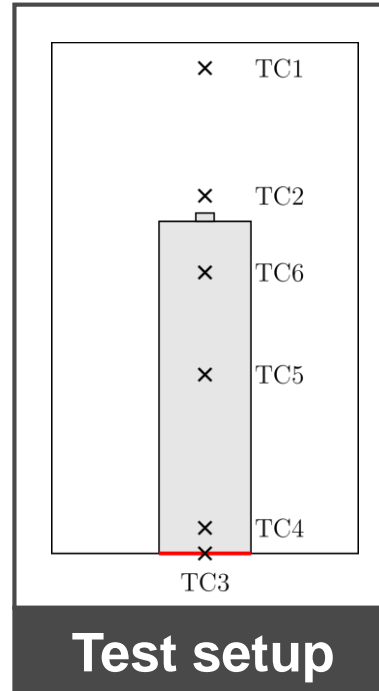
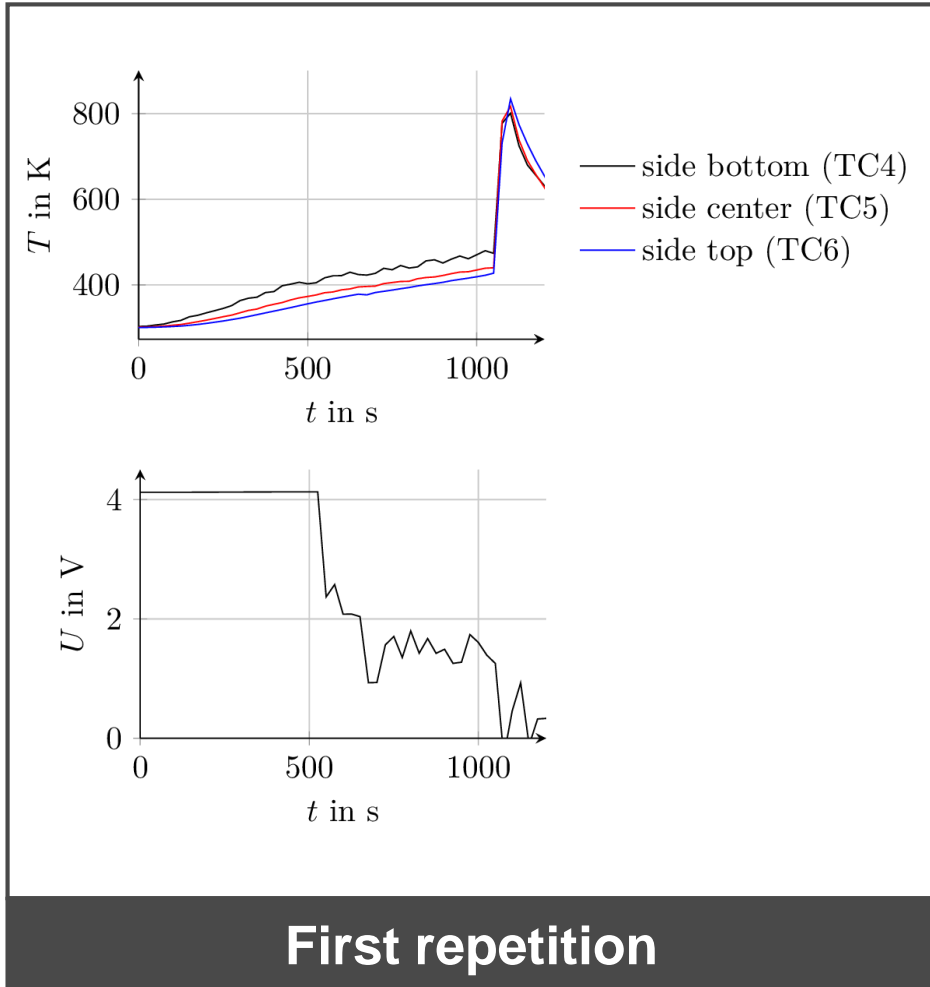


Overheat test of a battery cell

18650 battery cell

fully charged
overheating at bottom

Overheat test of a battery cell



Abuse simulation of a single cell using LS Dyna

Multiphysics of battery cells

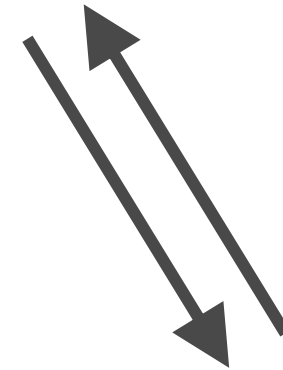
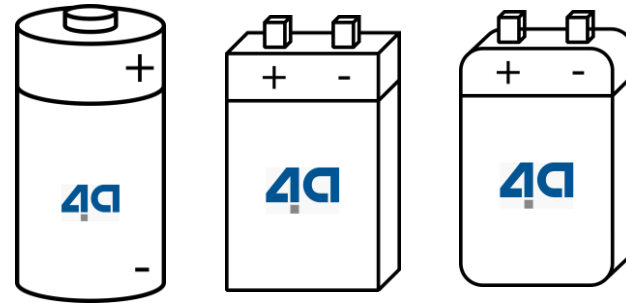
Thermal

ϑ
 λ
 \underline{q}
 T
 p
 k

T
 x
 k_1
 k_2
 k_3

Mechanical

T_{11} in MPa
 t in s
 F
 $\underline{\epsilon}$
 u
 \underline{T}
 $\underline{\sigma}$

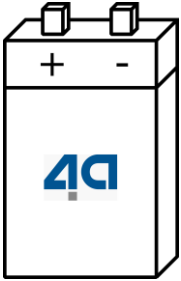
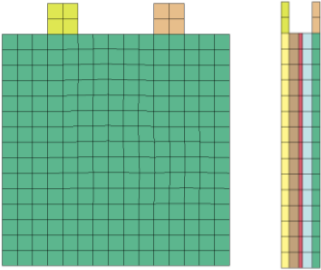
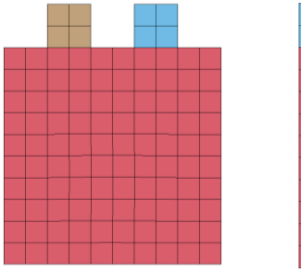
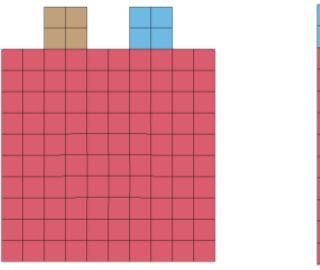


Electromagnetical

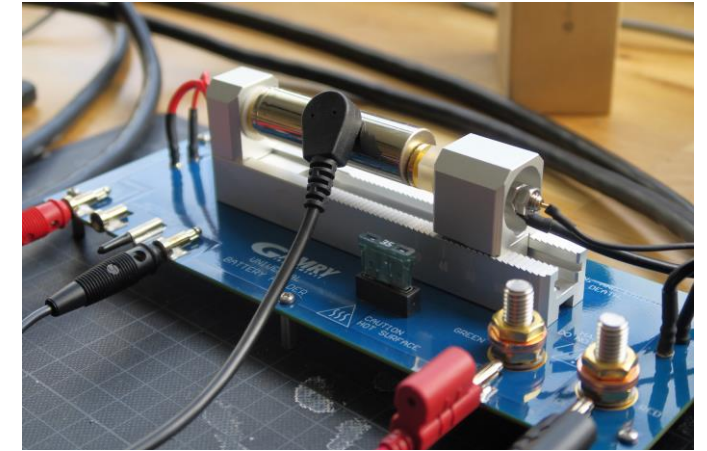
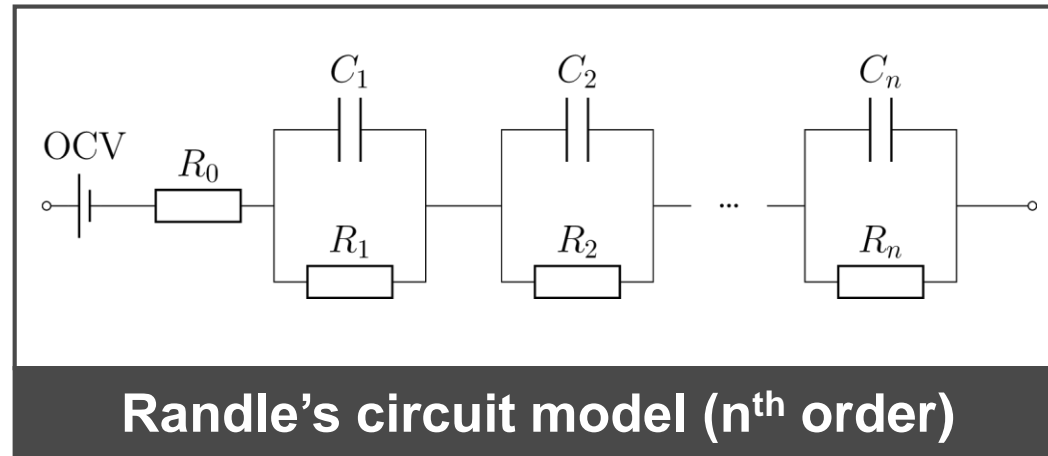
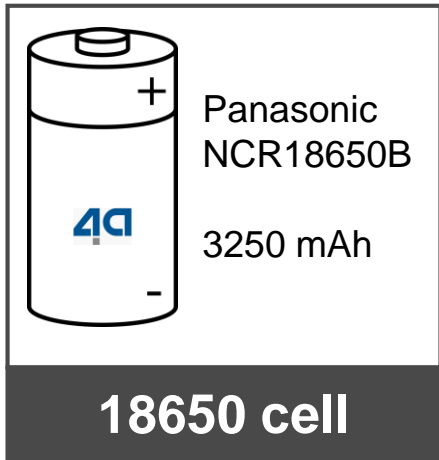
R
 U
 I
 C
 SOC



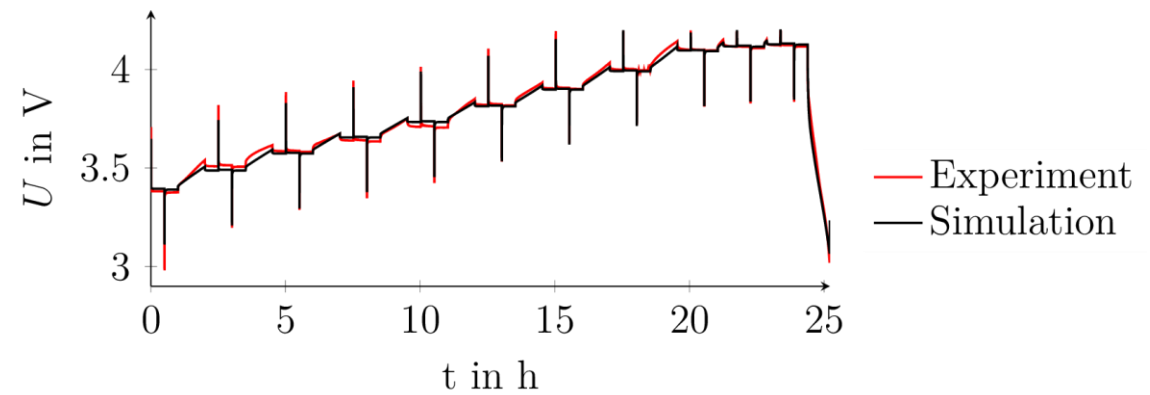
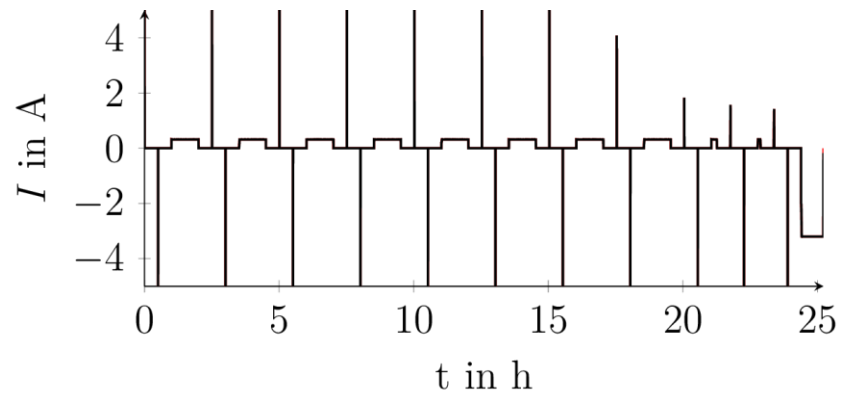
Modeling approaches in LS DYNA

	Solid layer model	Tshell model	Batmac model
			
Keyword	*EM_RANDLES_SOLID	*EM_RANDLES_TSHELL	*EM_RANDLES_BATMAC
Advantages	<ul style="list-style-type: none"> Analysis of the different layers is possible 	<ul style="list-style-type: none"> Beneficial modeling of thin cells Reduced computational effort 	<ul style="list-style-type: none"> Modeling with respect to mechanical and thermal problem Least computational effort
Disadvantages	<ul style="list-style-type: none"> Computational effort Characterization of the materials of the layers required 	<ul style="list-style-type: none"> Homogenized mechanical material model Behavior of the layers can not be analyzed in detail 	<ul style="list-style-type: none"> Homogenized material models Behavior of the layers can not be analyzed

Electrical modelling and characterization

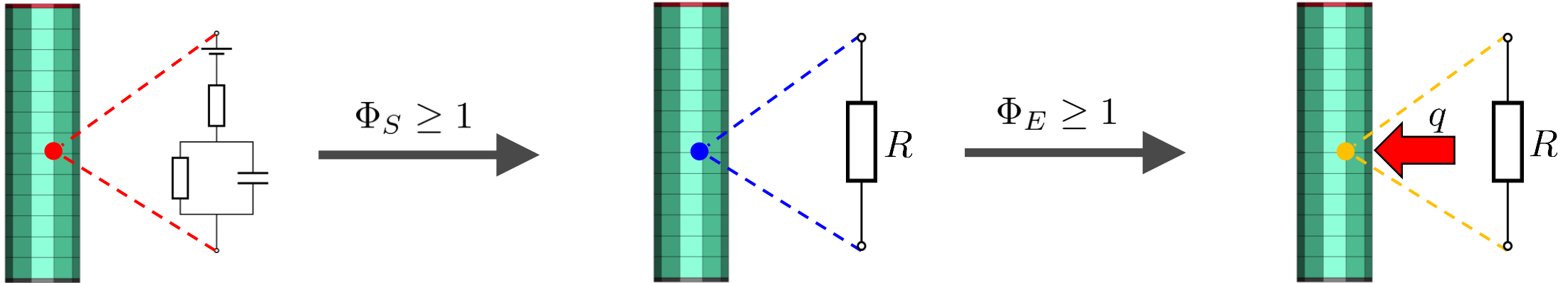


- Identification of the parameter based on the 4a HPPC test



Abuse simulation of a single cell

- Modeling of the electrical behavior, the internal short circuit and the exothermal reaction



Initiation criterion:

$$\Phi_S (T, \text{SOC}, \underline{\underline{\varepsilon}}) \geq 1$$

Short resistance:

$$R = \text{const.}$$

Internal short circuit

Initiation criterion:

$$\Phi_E (T) \geq 1$$

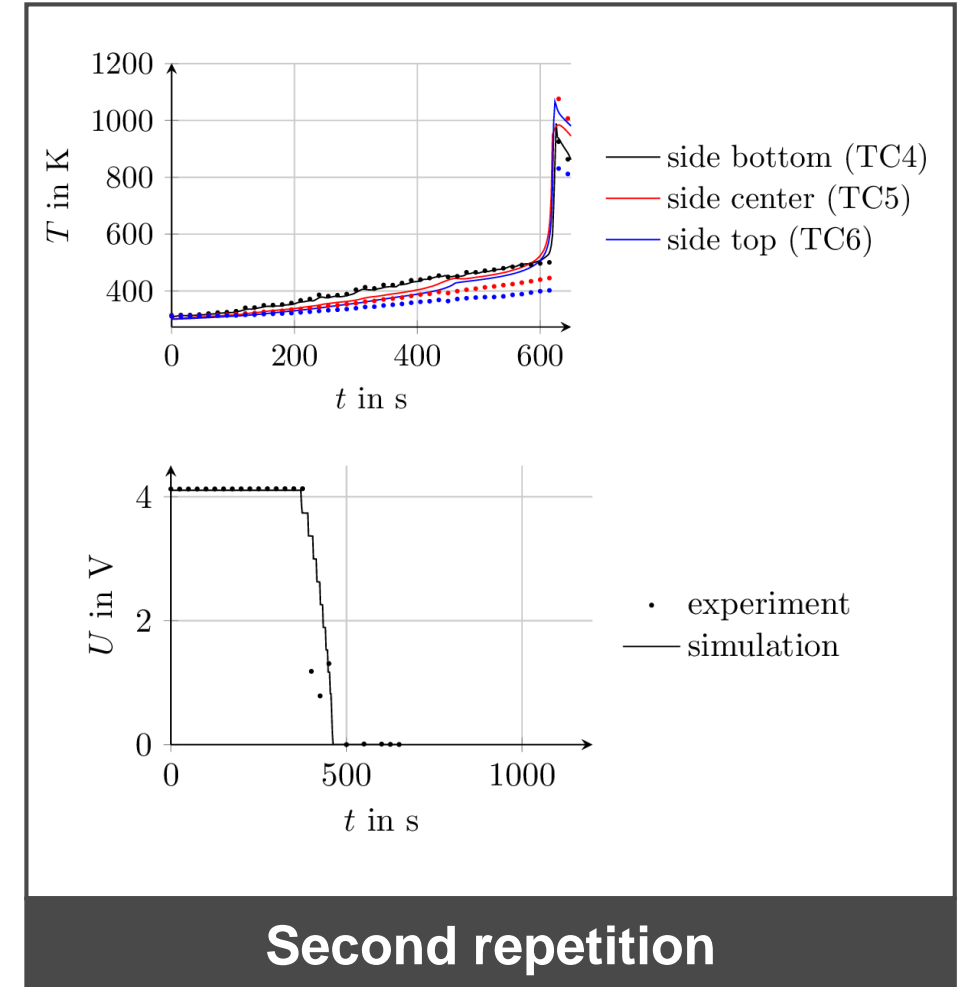
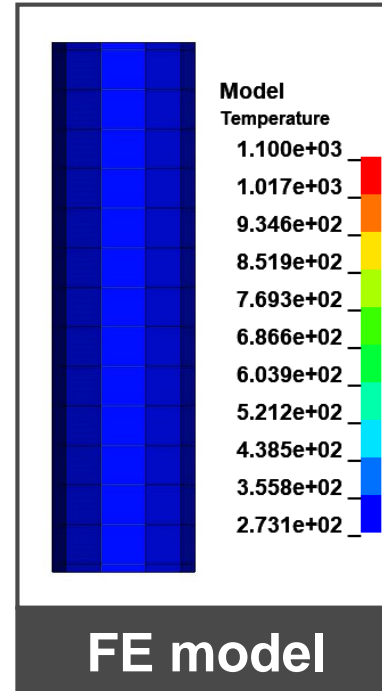
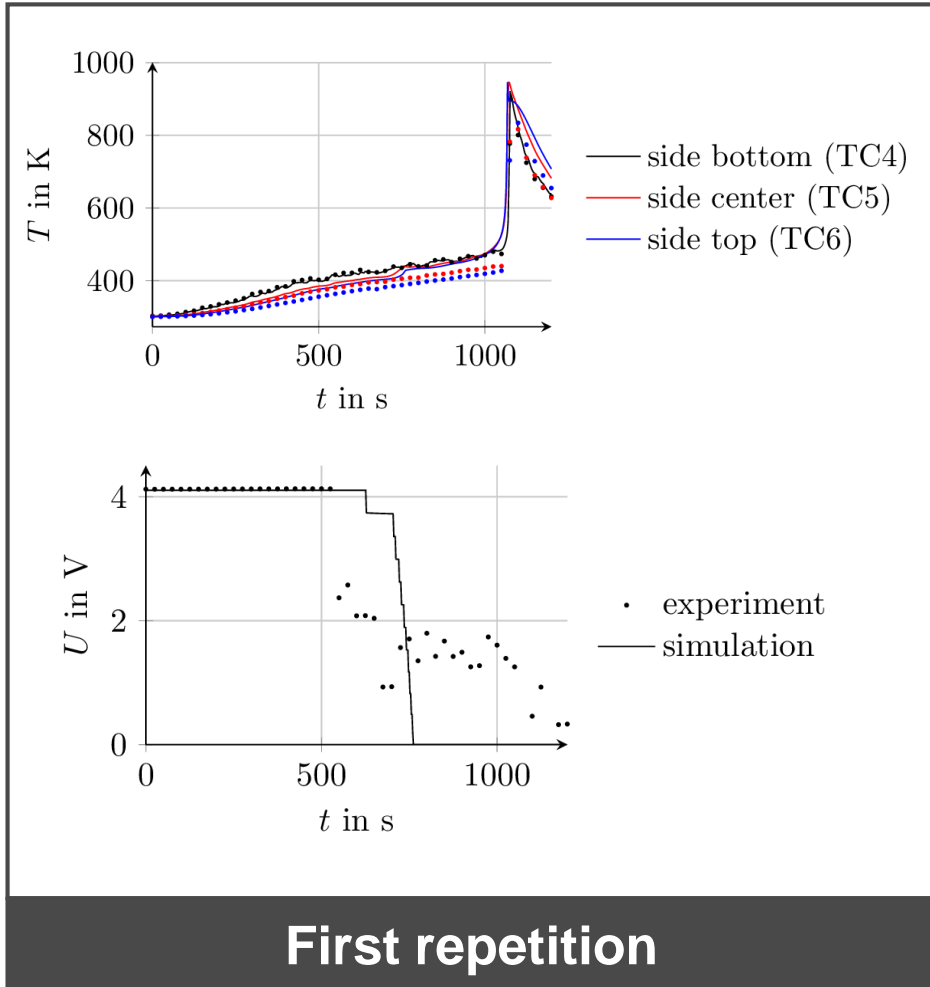
Additional heat source:

$$q (T)$$

Exothermal reaction

Abuse simulation of a single cell

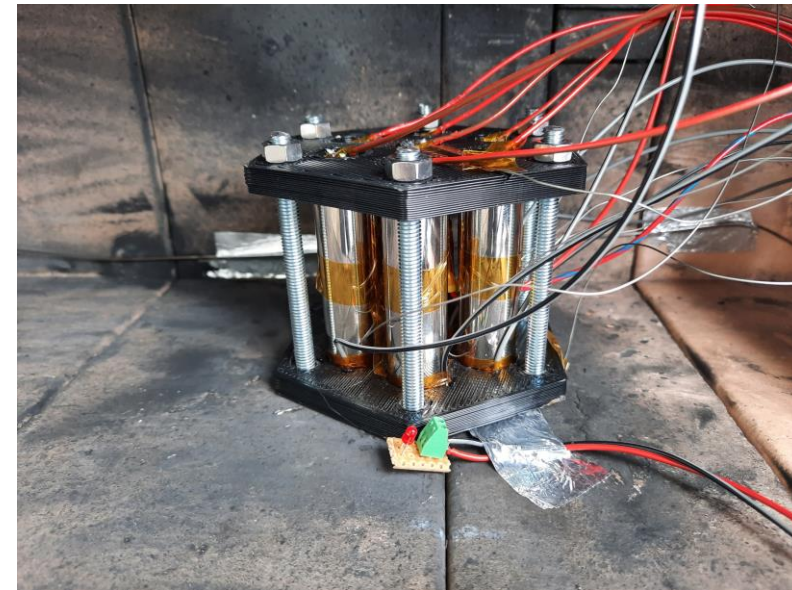
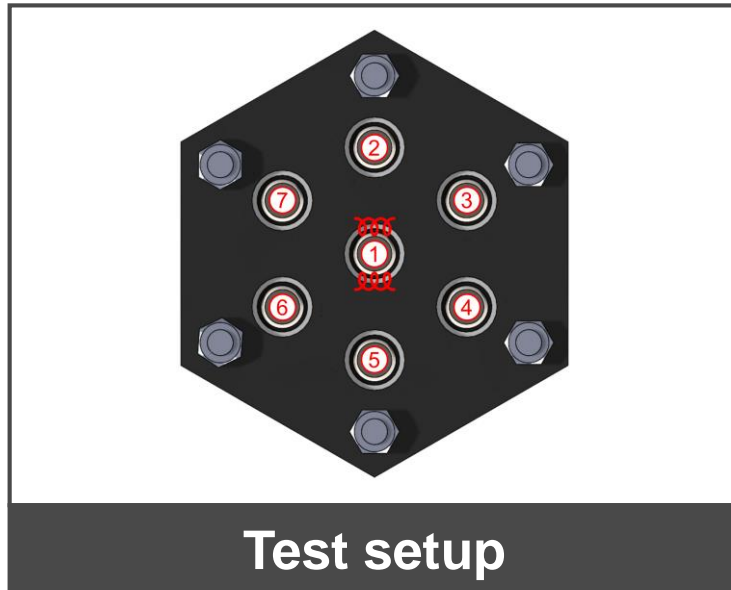
Overheat test – results of parameter identifications



Integration of a single cell model in a simulation of a multi-cell mockup

Experimental investigation

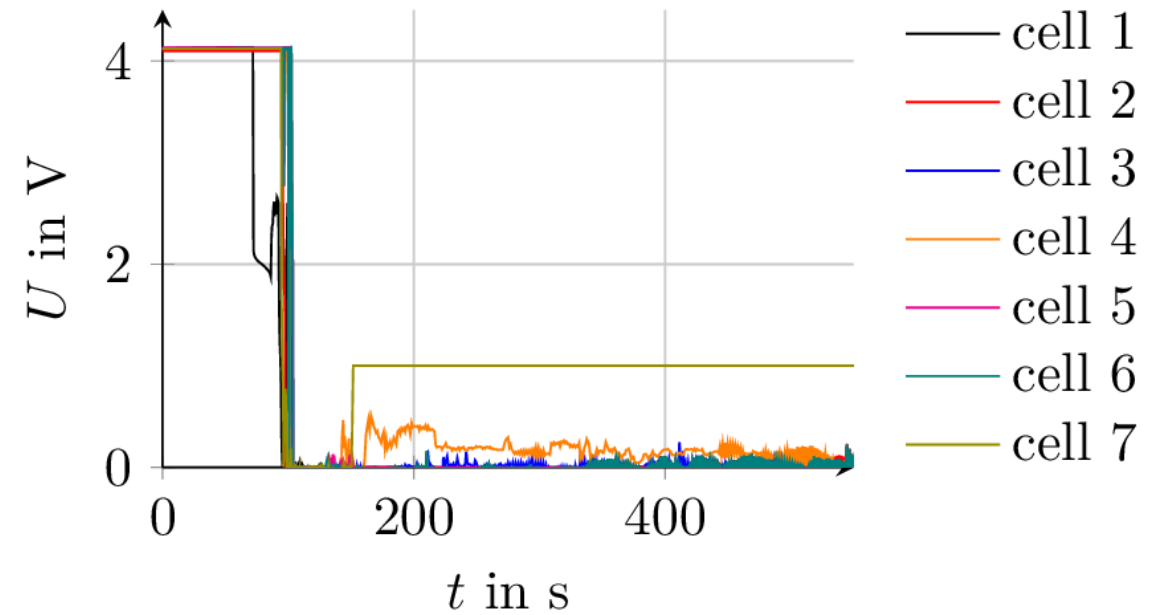
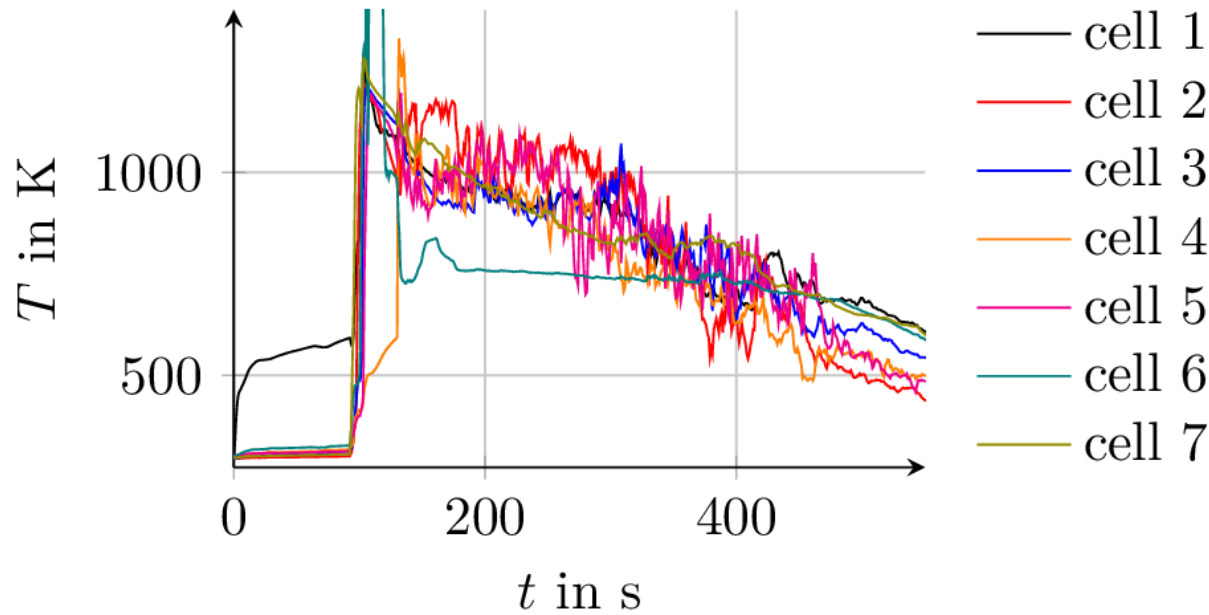
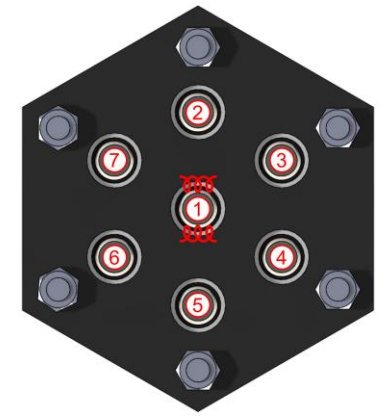
- Thermal runaway of the center cell induced by heating with a heating wire
- Temperature and voltage measurement of each cell
- Video recording with high-speed camera



Mock-up with seven 18650 battery cells
equal distances

Experimental investigation

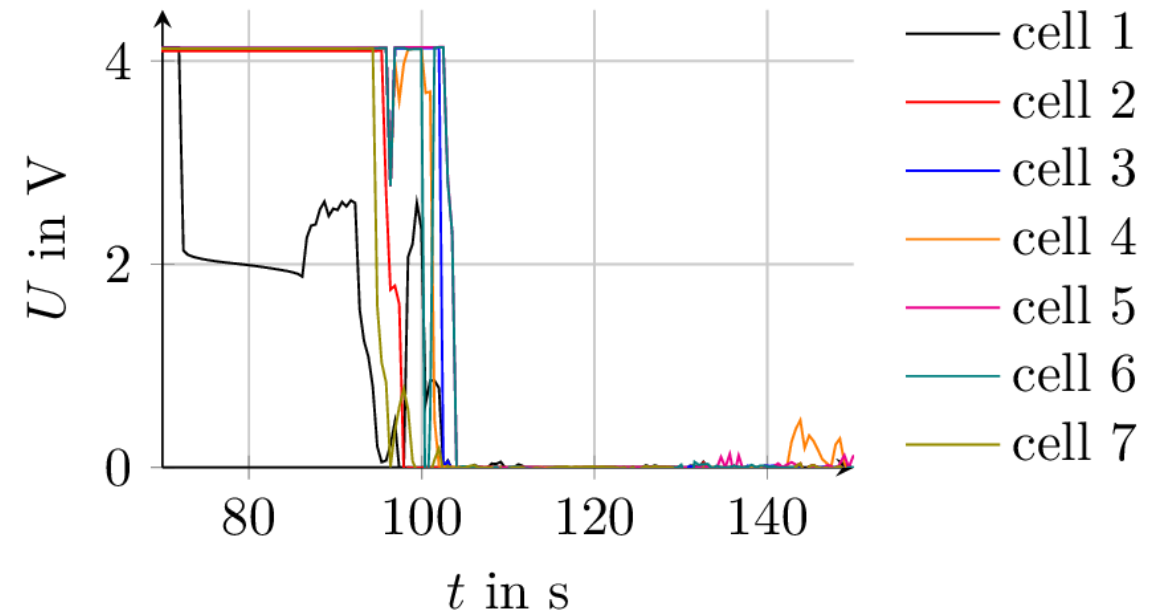
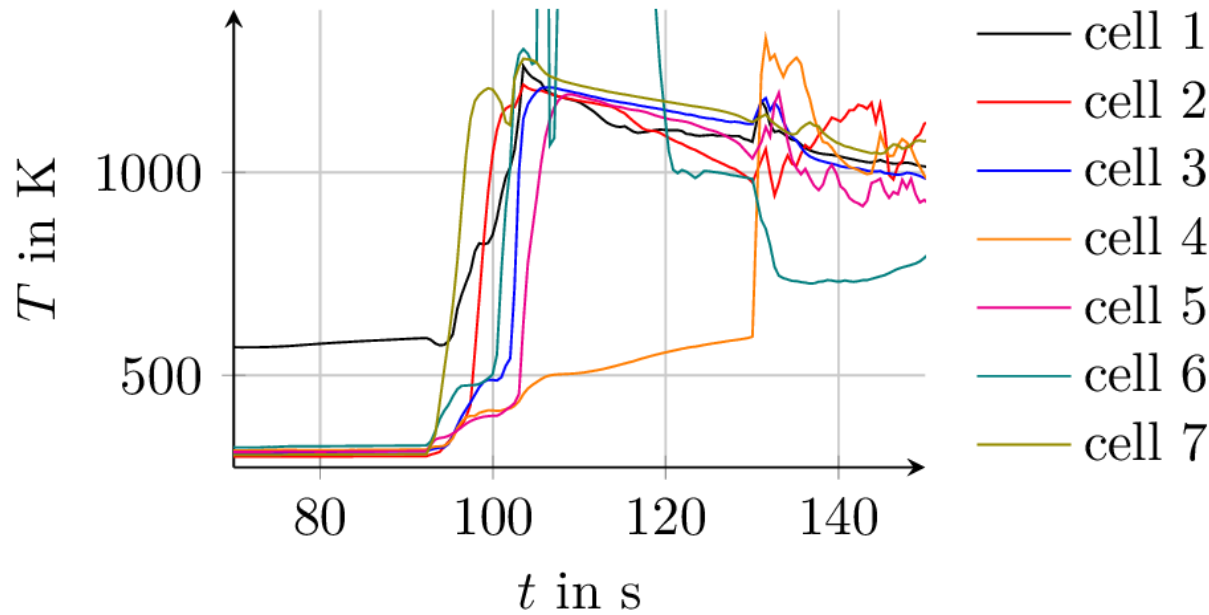
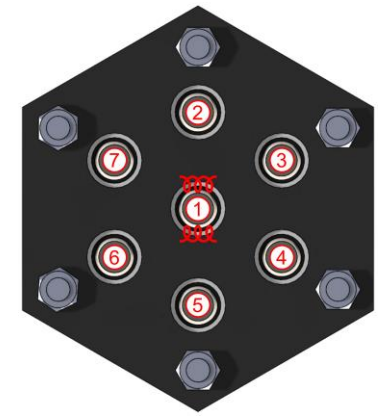
Behavior of all cells



*Thermocouple at cell 6 was broken within the test

Experimental investigation

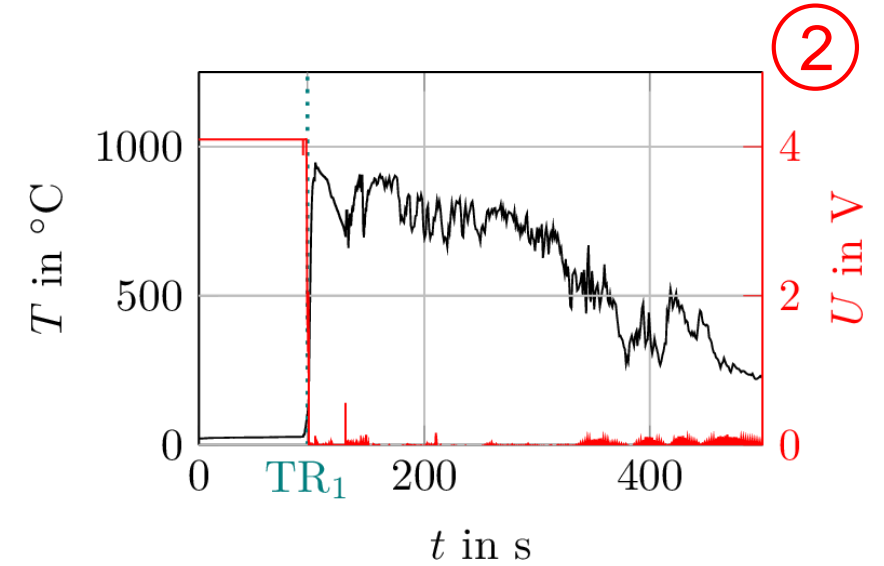
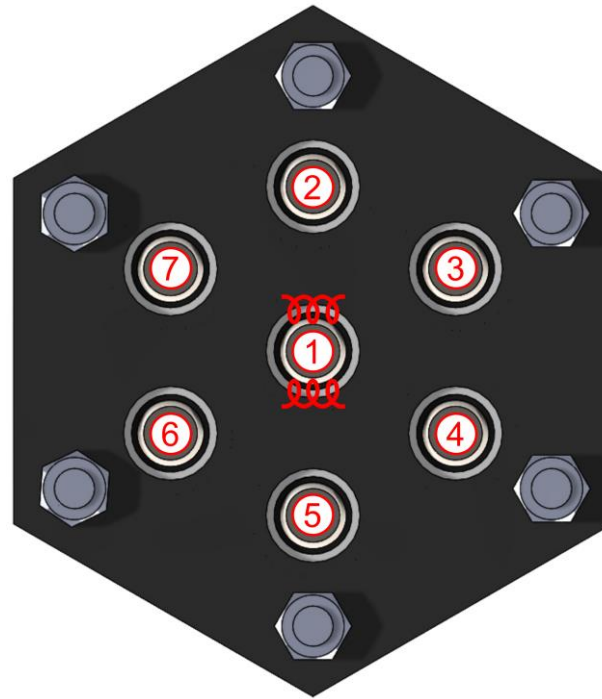
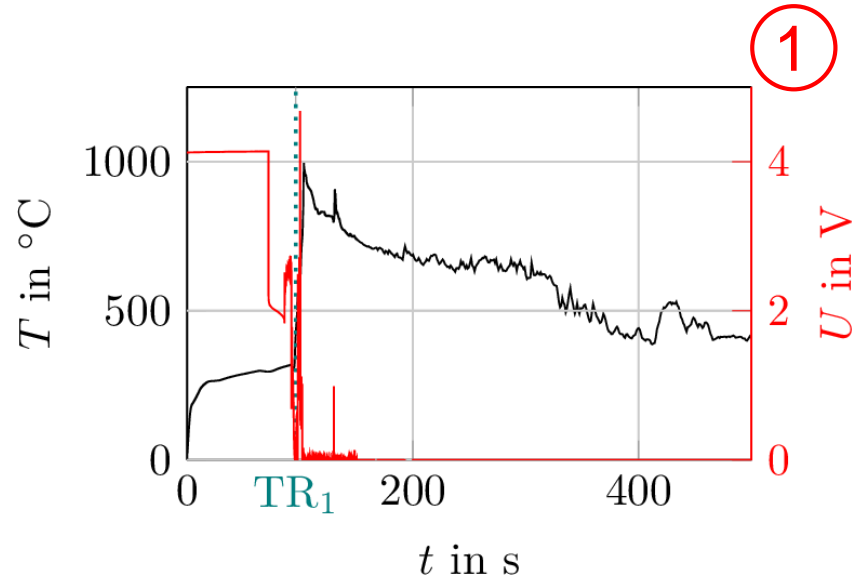
Behavior of all cells



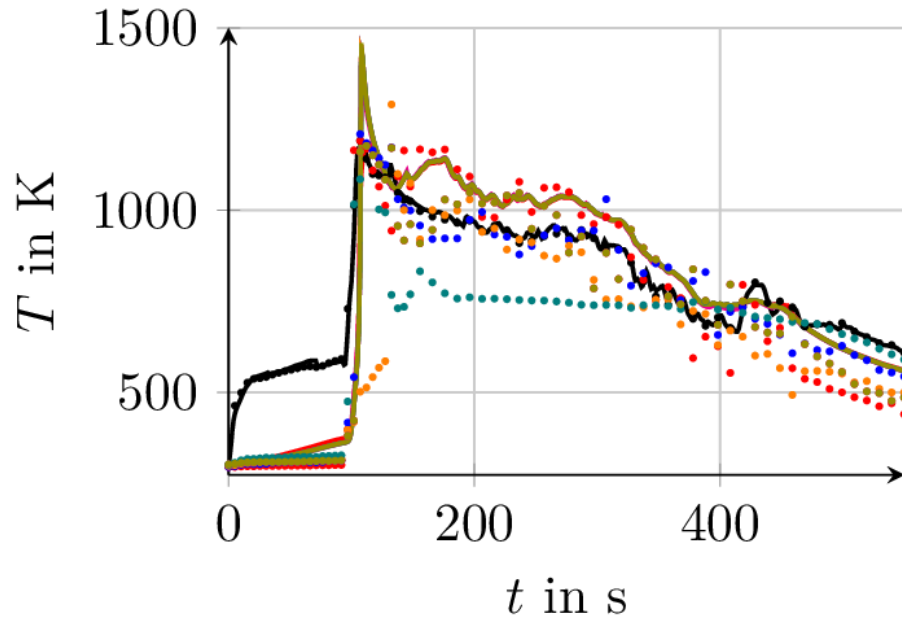
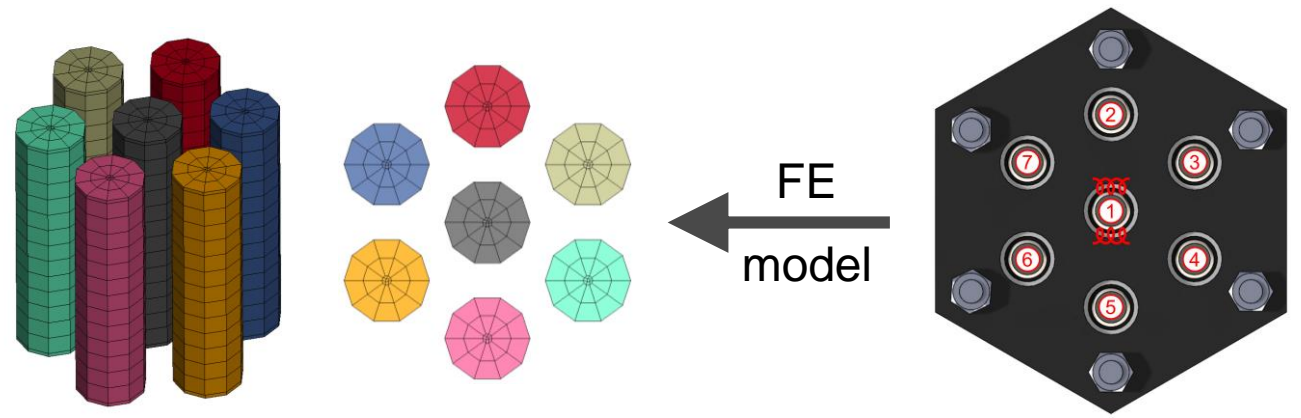
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Experimental investigation

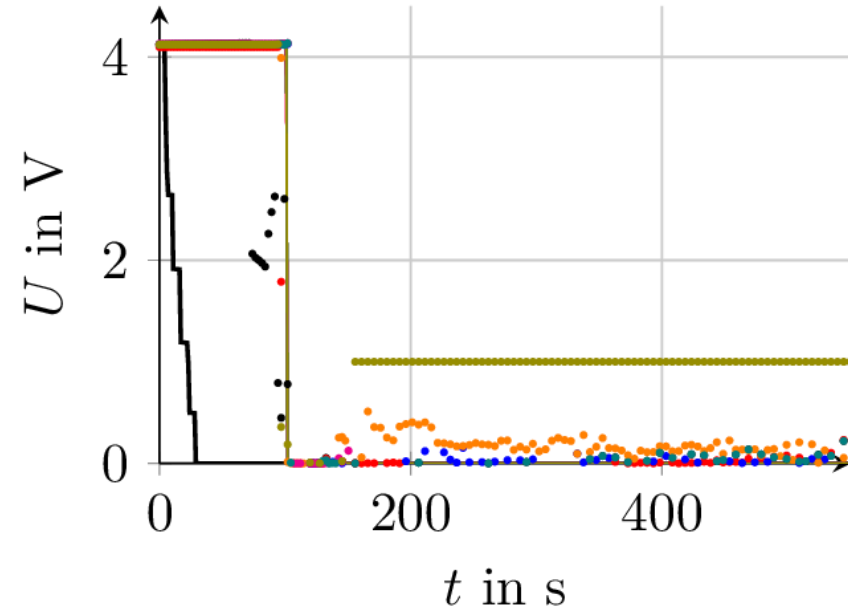
Behavior of cell 1 and 2



Simulation results



- cell 1
- cell 2
- cell 3
- cell 4
- cell 5
- cell 6
- cell 7

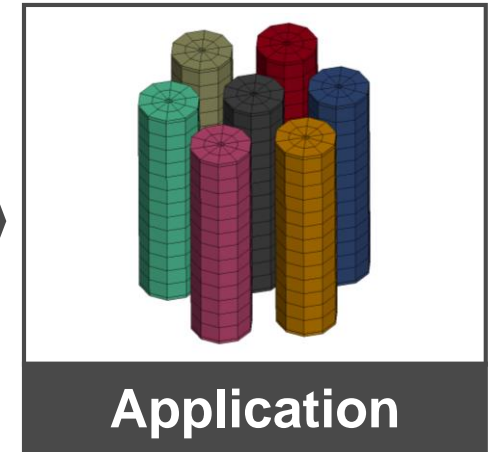
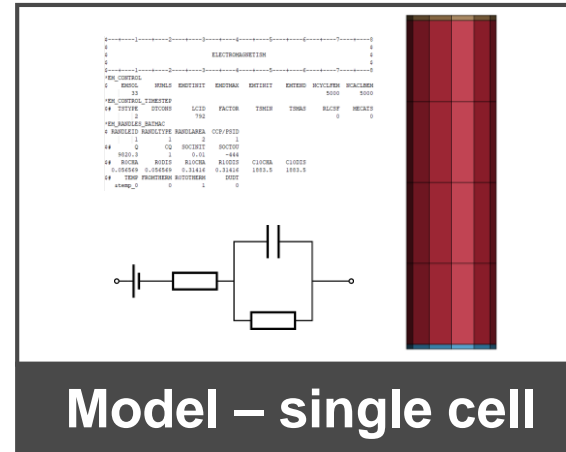
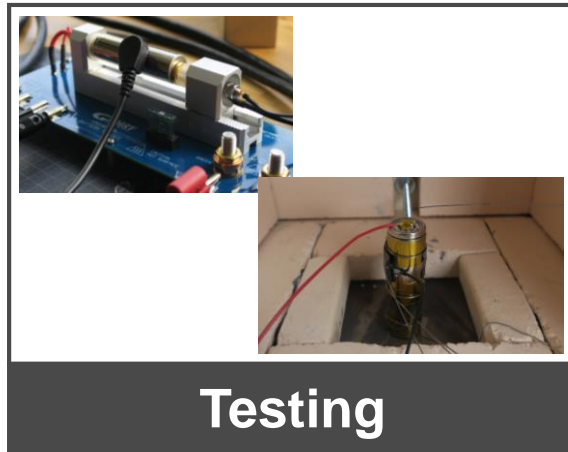


- cell 1
- cell 2
- cell 3
- cell 4
- cell 5
- cell 6
- cell 7

• experiment — simulation

Conclusion and outlook

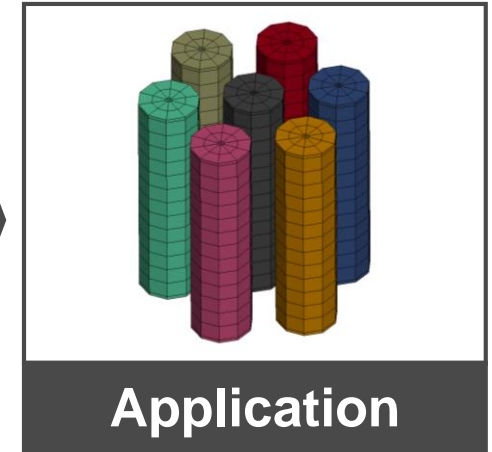
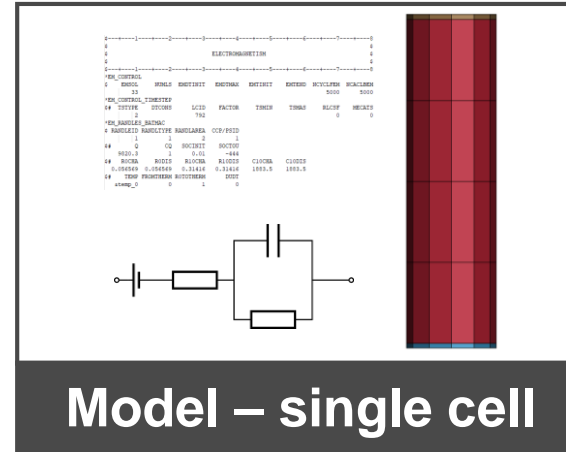
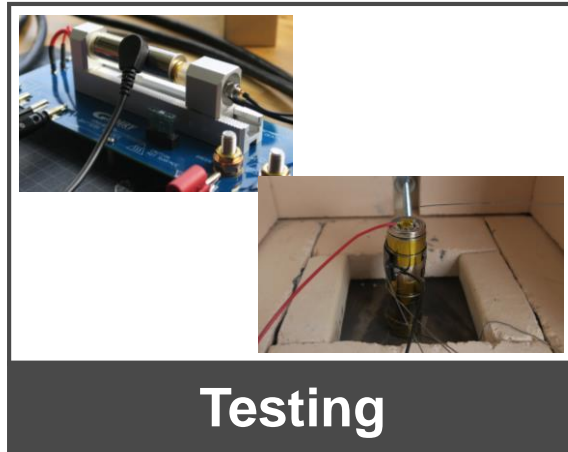
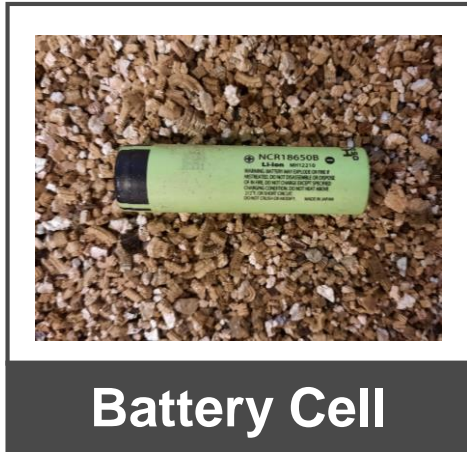
Conclusion



Outlook

- Development of test setups for further characterizations of battery cells especially within the thermal runaway
- Automatic identification of the parameters required for the resulting FE model
- Optimization of battery packs addressing the thermal propagation behavior

Conclusion



Outlook

- Development of test setups for further characterizations of battery cells especially within the thermal runaway
- Automatic identification of the parameters required for the resulting FE model
- Optimization of battery packs addressing the thermal propagation behavior

Improve your developments with our expertise in testing and simulation!

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