ENGINEERING

excellence in …
plastics simulation
testing equipment
lightweight products

Generation of abuse simulation models of battery cells and battery packs

Martin Schwab, Robert Kießling

WCCM-APCOM 2022

Testing and Identification

Material

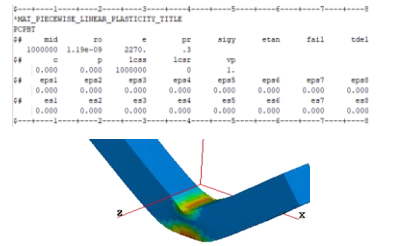
IMPETUS

Testing

VALIMAT

Identification

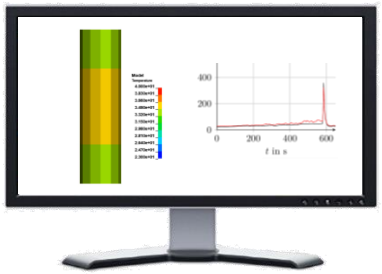
MATERIAL cards



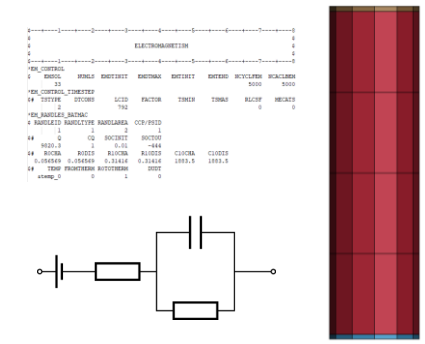
Material model

Battery Cell

Testing



Identification



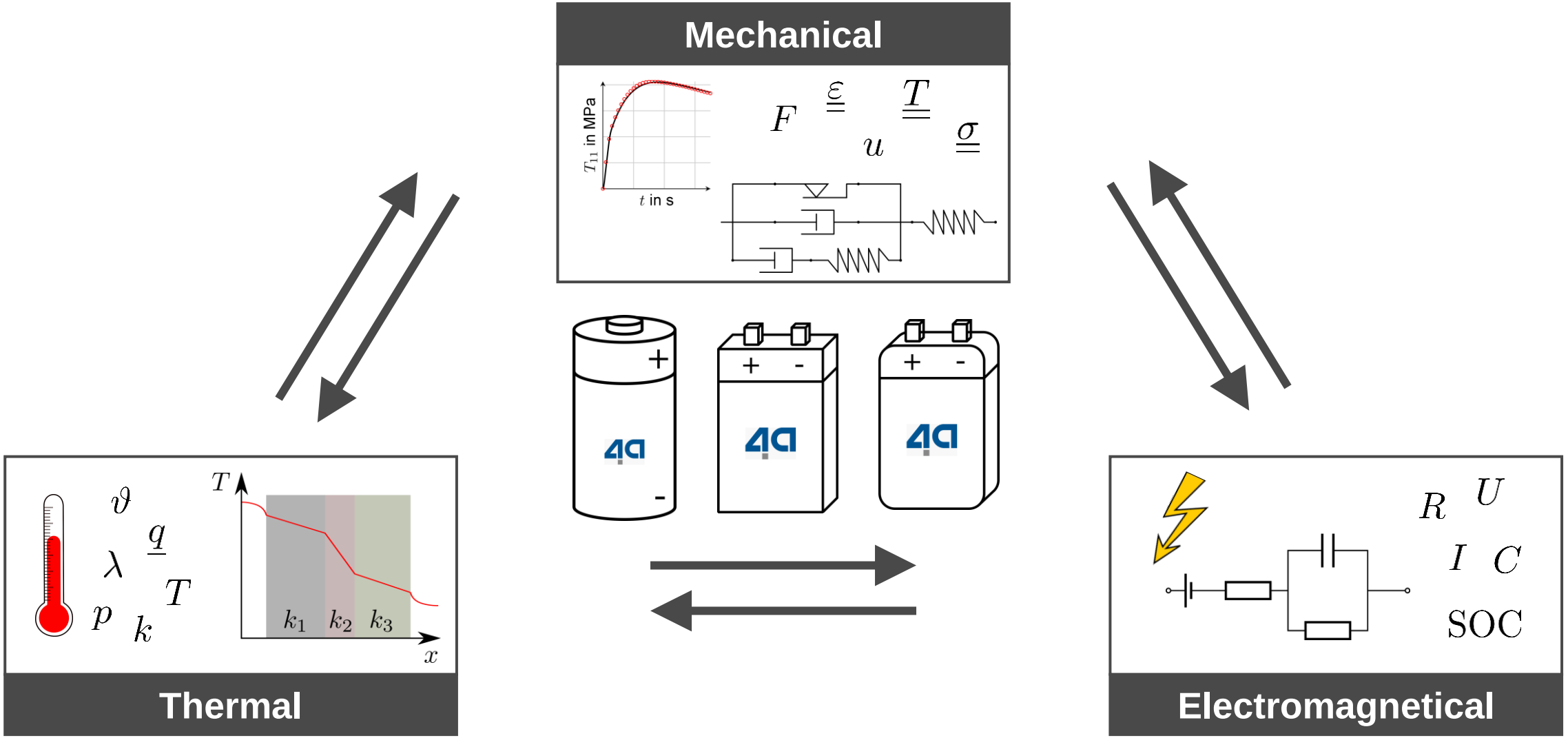
FE Model

Outline

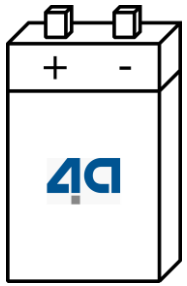
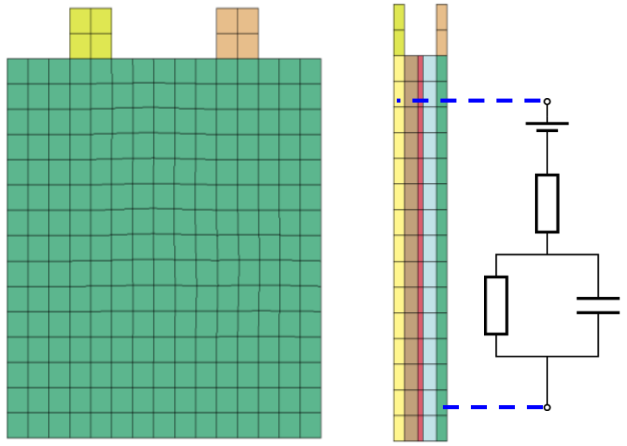
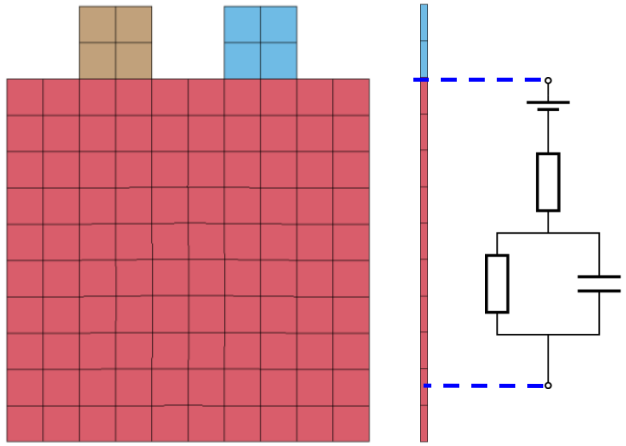
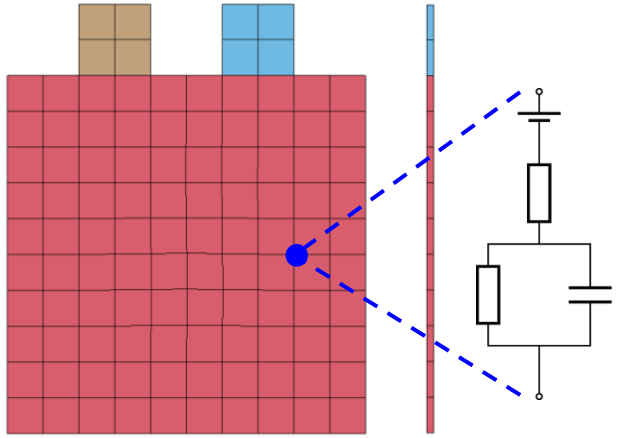
1. Generation of abuse simulation models of a single battery cell using LS Dyna
2. Abuse testing and simulation of a single battery cell
3. Application of a single cell model within the simulation of multi-cell mockups
4. Conclusion and outlook

Generation of abuse simulation models of a single battery cell using LS Dyna

Multiphysics of battery cells

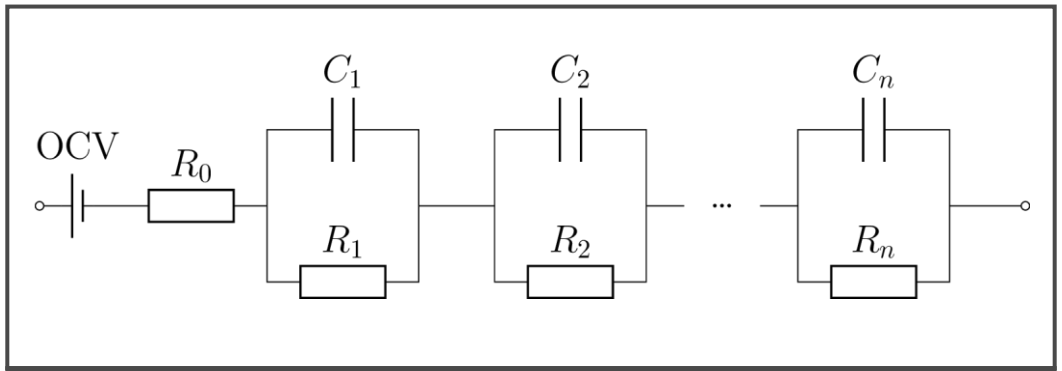


Modeling approaches in LS DYNA

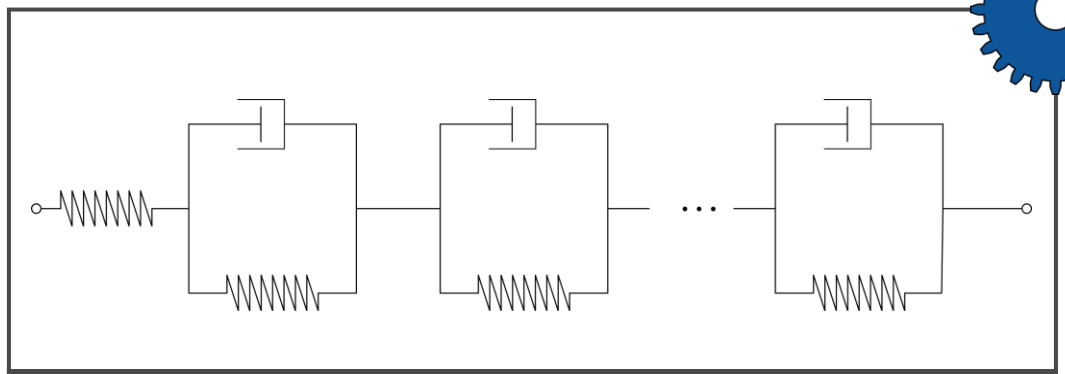
	Solid layer model	Tshell model	Batmac model
	 		
Keyword	*EM_RANDLES_SOLID	*EM_RANDLES_TSHELL	*EM_RANDLES_BATMAC
Characteristics	+ Analysis of the different layers is possible – Computational effort	+ Benefical modeling of thin cells – Behavior of the layers can not be analyzed in detail	+ Modeling with respect to mechanical and thermal problem – Behavior of the layers can not be analyzed

Electrical modelling and characterization

- electrical behavior is covered by a circuit model

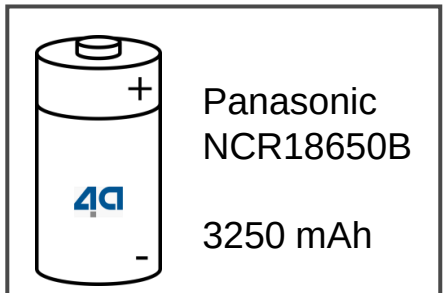


Randle's circuit model (nth order)



Kelvin-Voigt model (nth order)

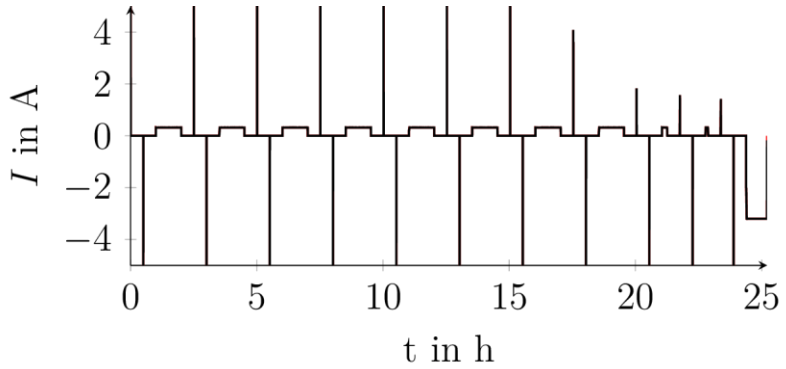
- parameter as well as the OCV-SOC curve are identified from the 4a HPPC test

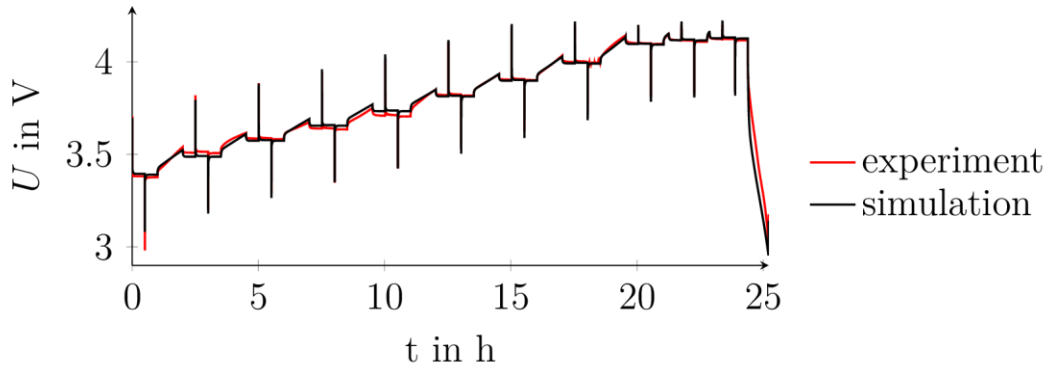


Panasonic
NCR18650B

3250 mAh

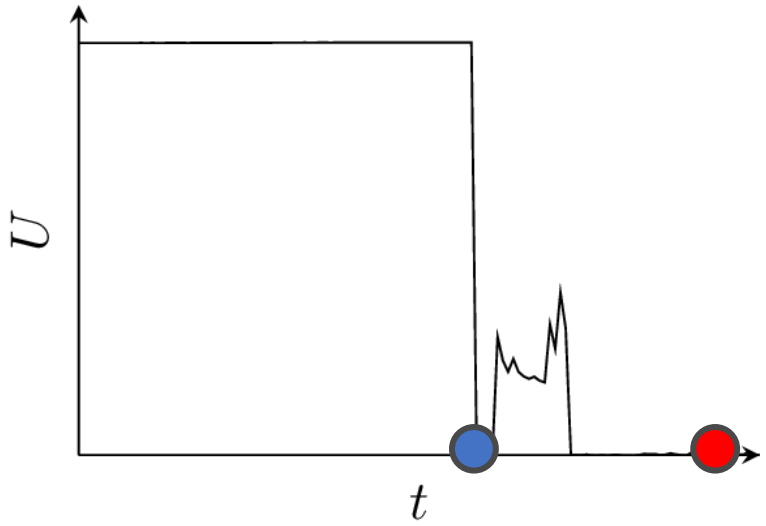
18650 cell

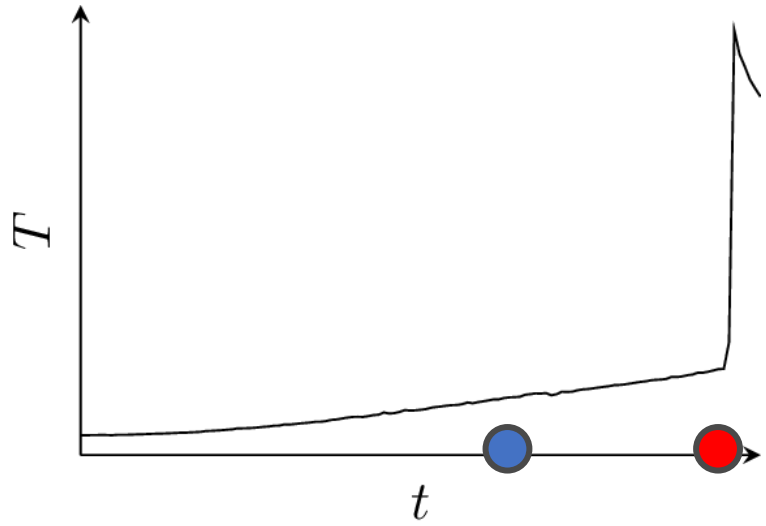




Characteristic of the abuse of a battery cell

- Course of voltage and temperature because of overheating

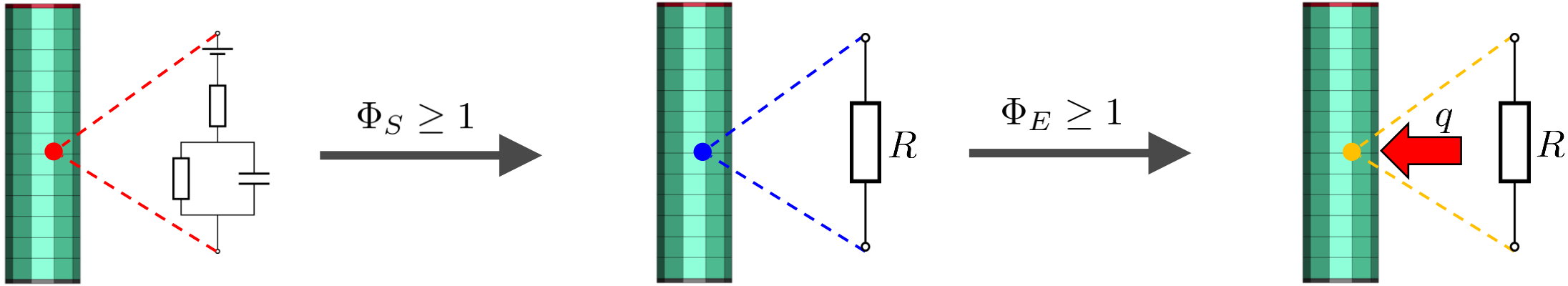




- Characteristic points and effects:
  - **Internal short circuit:** drop of the voltage
  - **Exothermic reaction**: spontaneous increase of the temperature

Abuse simulation of a single cell

- Modeling of the internal short circuit and the exothermal reaction



Initiation criterion:

$$\Phi_S\left(T, \mathrm{SOC}, \underline{\underline{\varepsilon}}\right) \geq 1$$

Short resistance:

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

Internal short circuit

Initiation criterion:

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

Additional heat source:

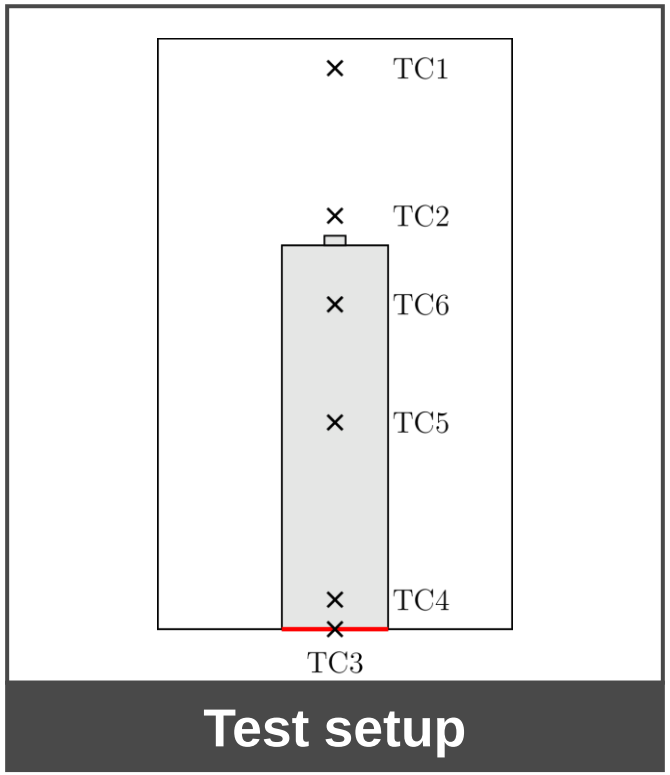
$$q\left(T\right)$$

Exothermal reaction

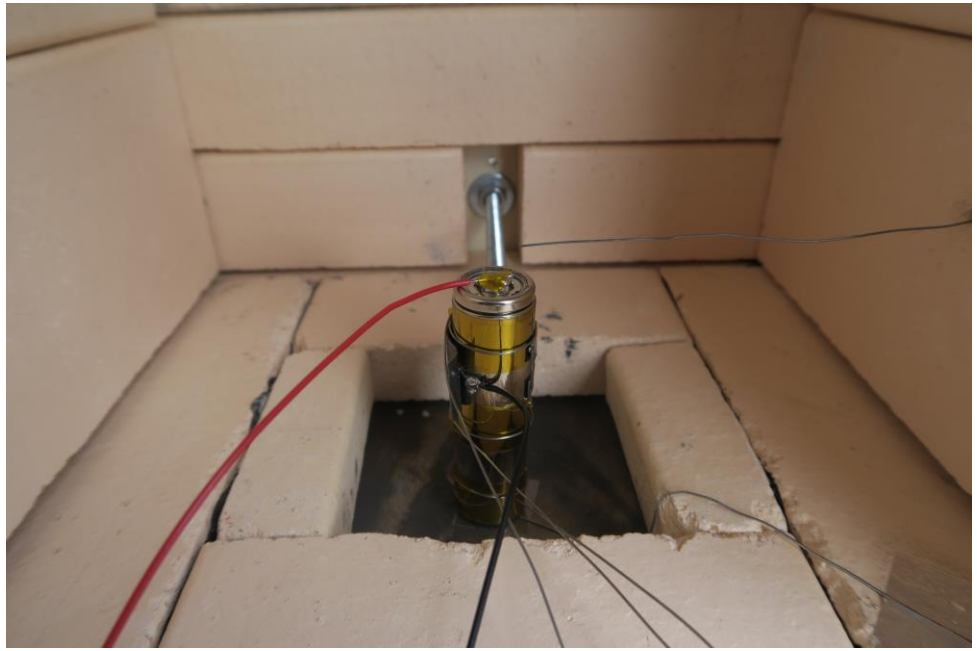
Abuse testing and simulation of a single battery cell

Overheat test of a single 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



Test setup



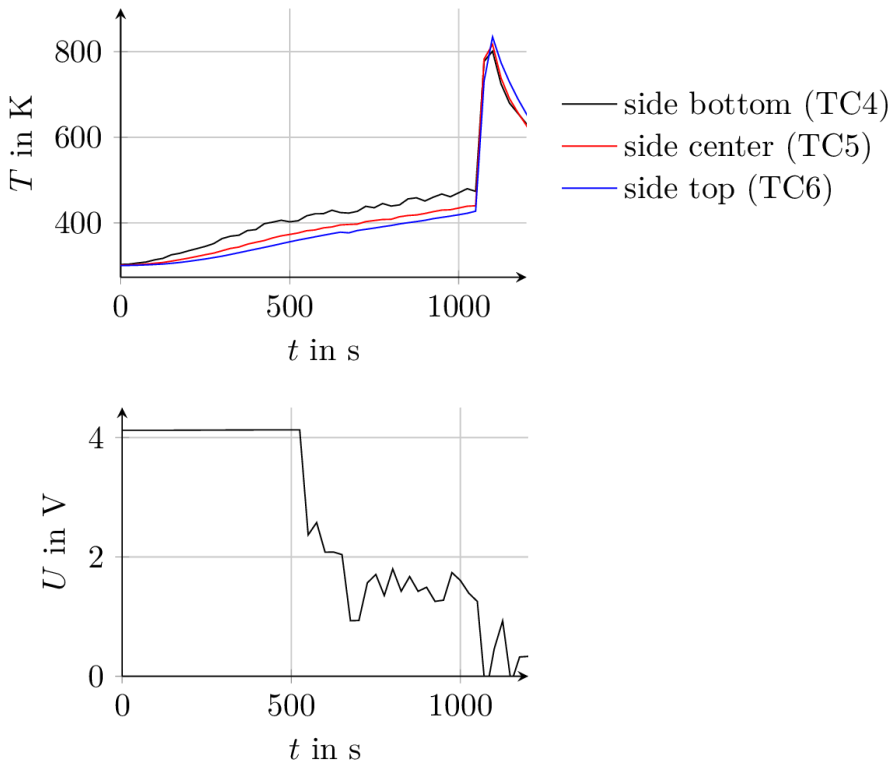
Overheat test of a single battery cell

18650 battery cell

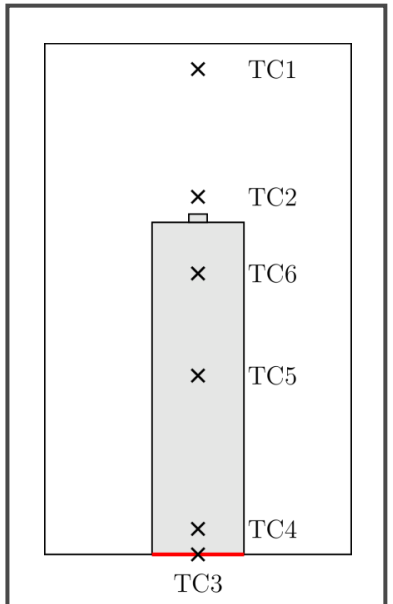
fully charged
overheating at bottom

Overheat test of a single battery cell

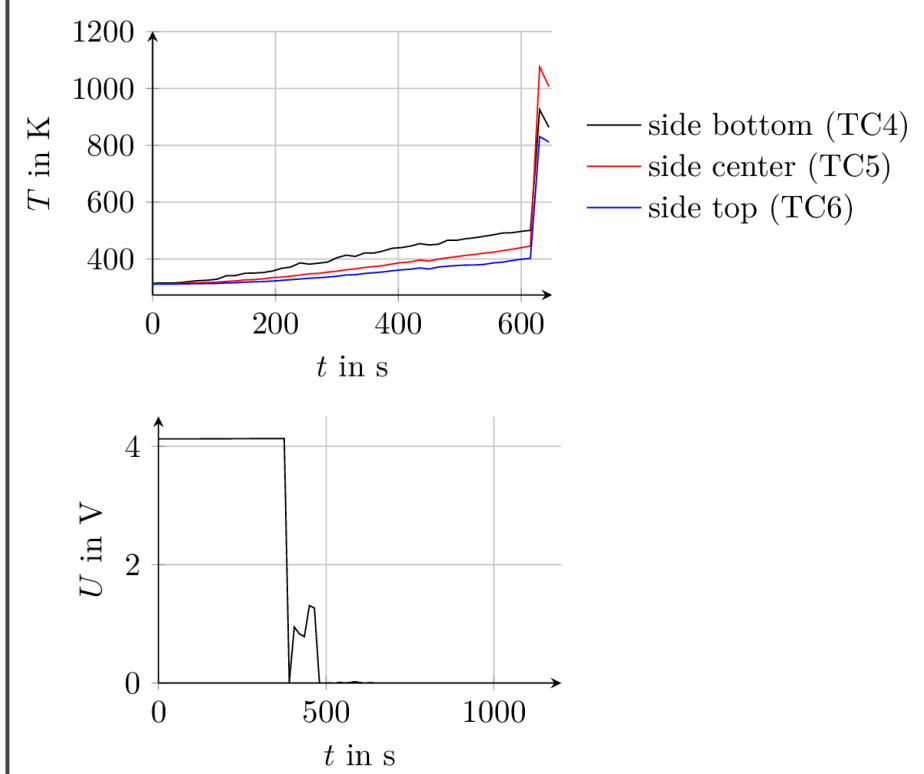
Experimental results



First repetition



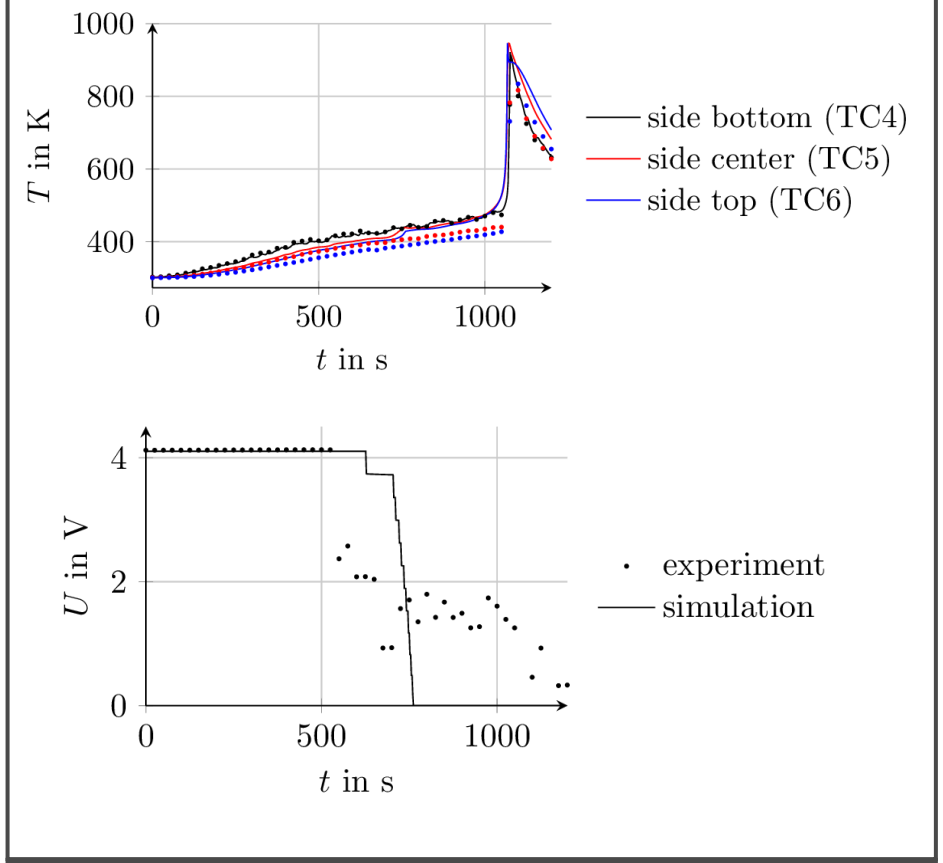
Test setup



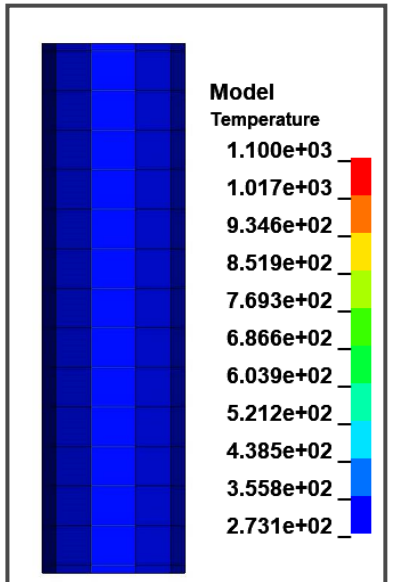
Second repetition

Overheat test of a single battery cell

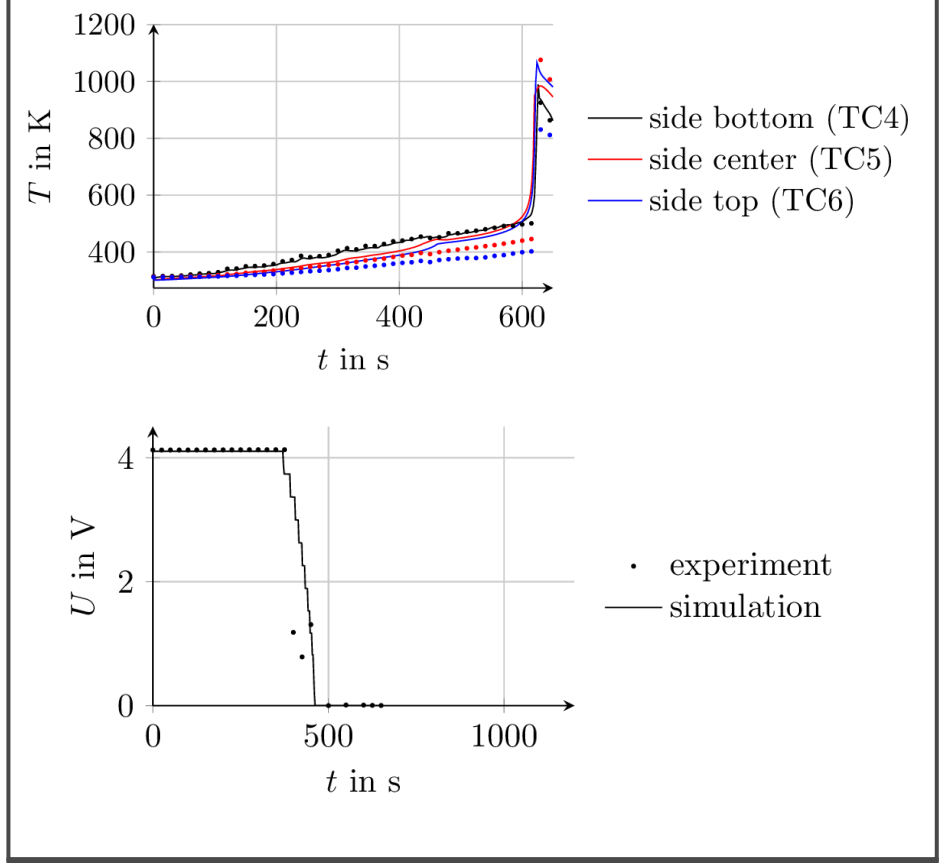
Comparison of experimental and simulative data



First repetition



FE model

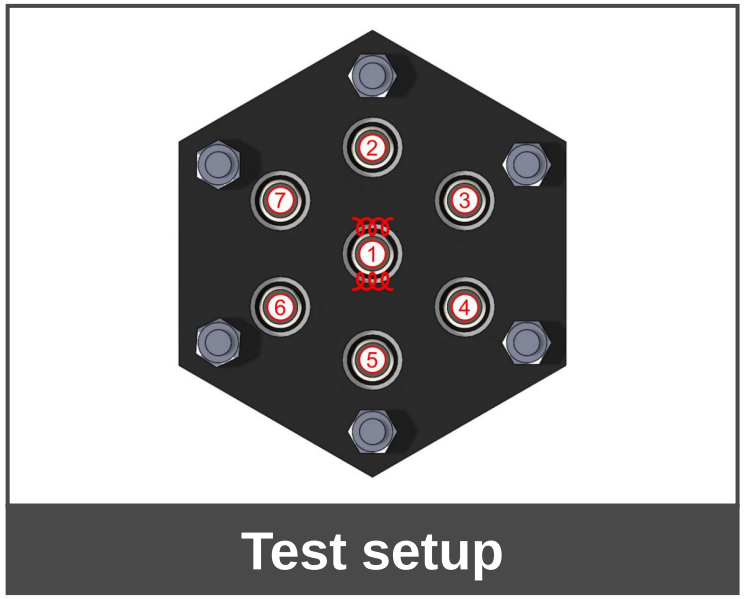


Second repetition

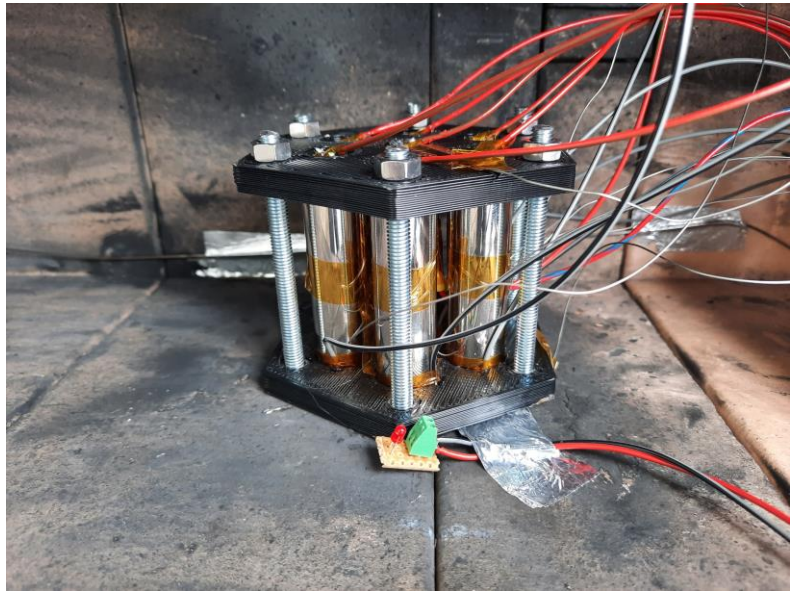
Application of a single cell model within the simulation of multi-cell mockups

Mockup with equal distances
Experimental investigation

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



Test setup



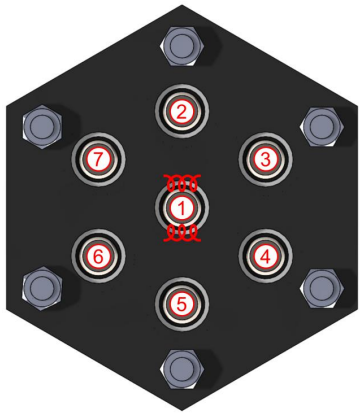
Mockup with equal distances
Experimental investigation

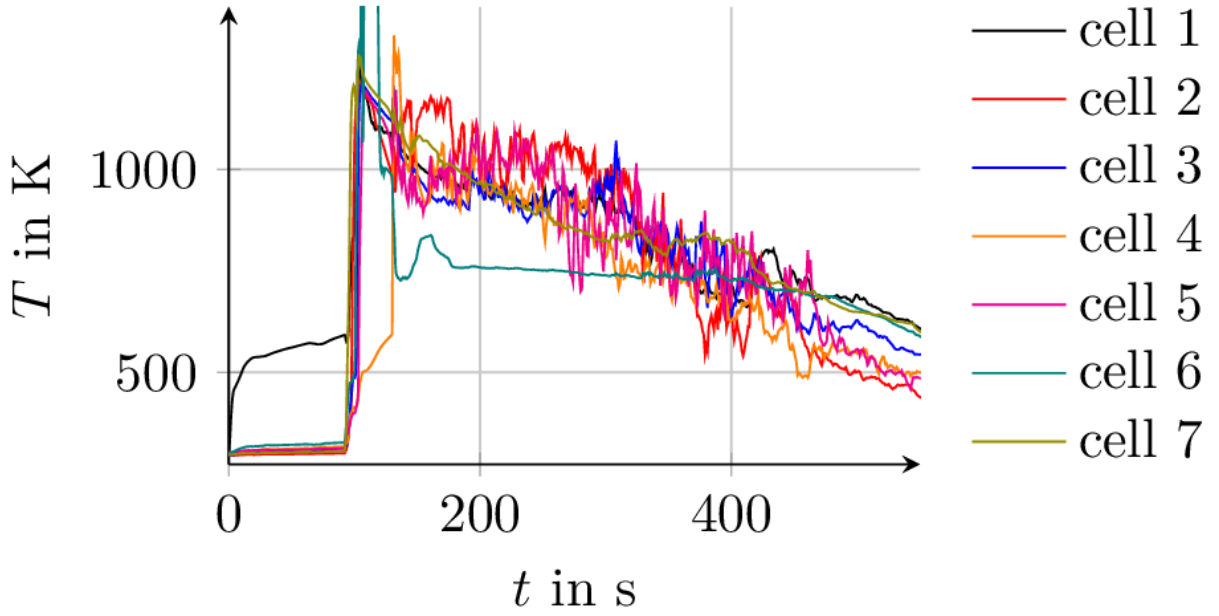
Mock-up with seven 18650 battery cells

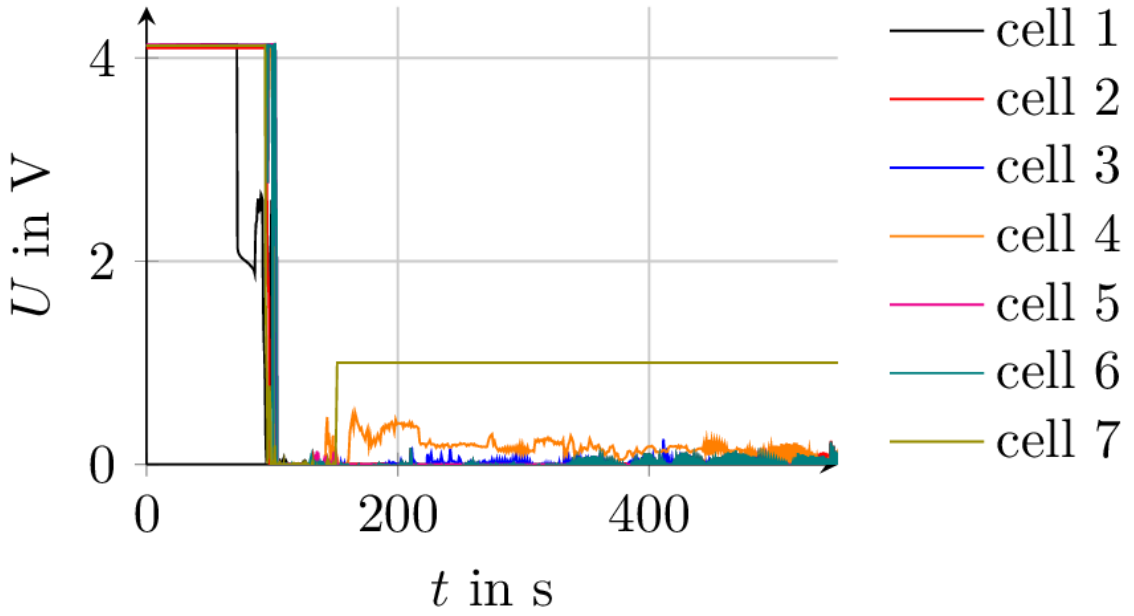
equal distances

Mockup with equal distances

Experimental investigation – behavior of all cells



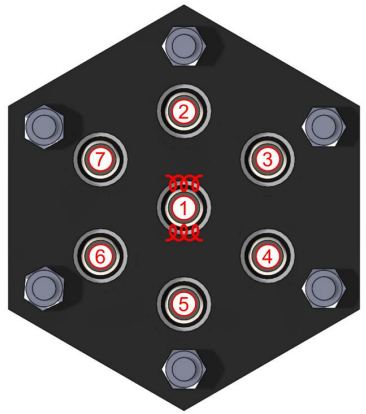


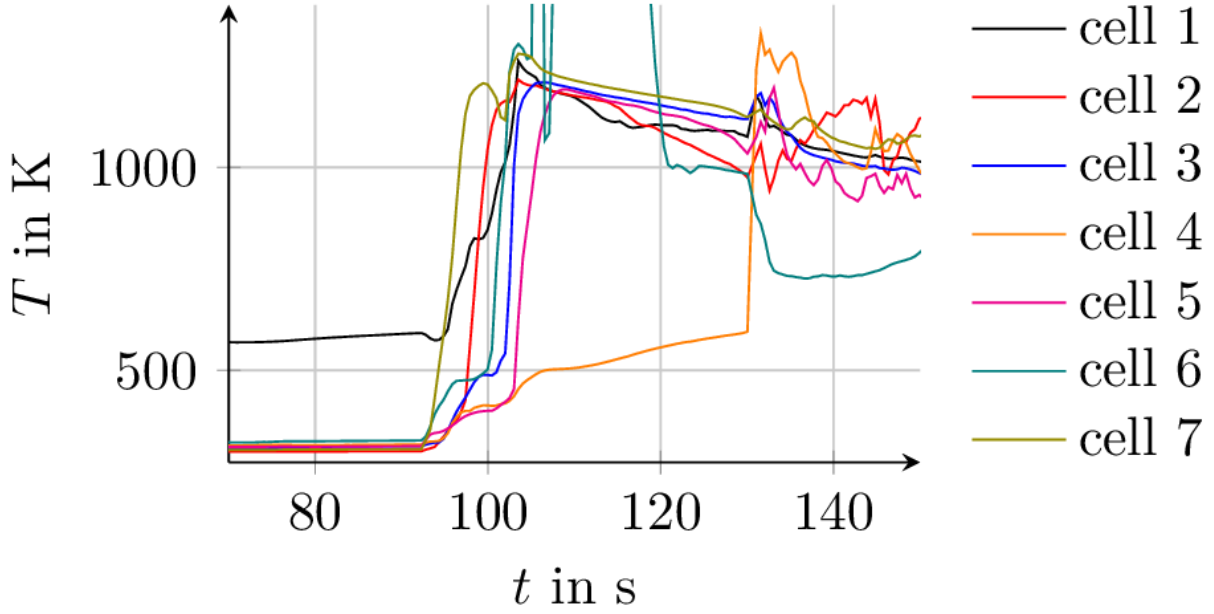


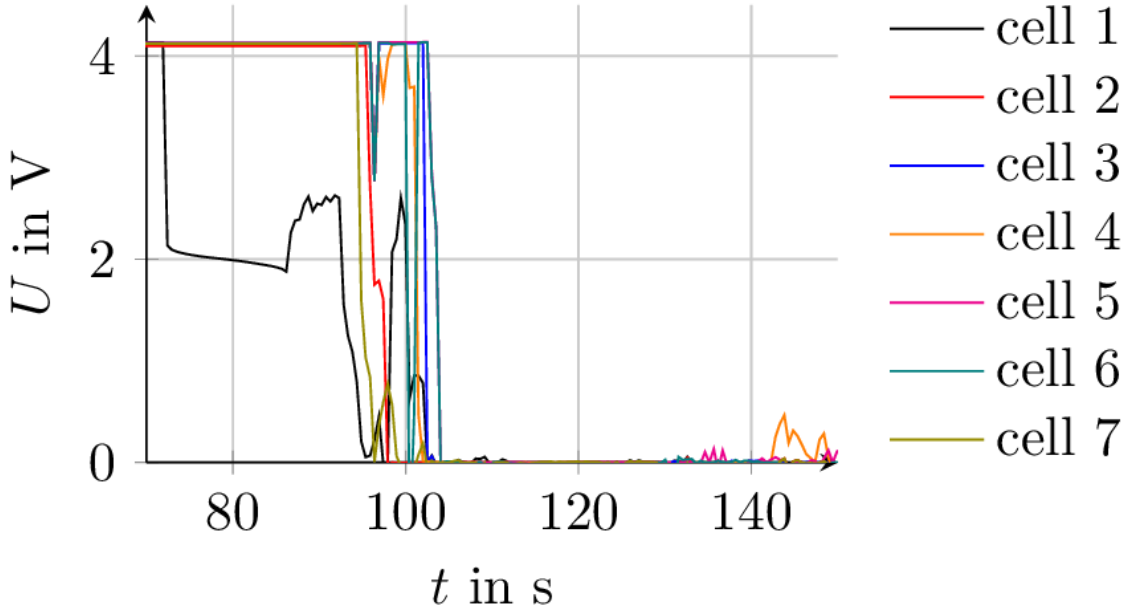
*Thermocouple at cell 6 was broken within the test

Mockup with equal distances

Experimental investigation – behavior of all cells



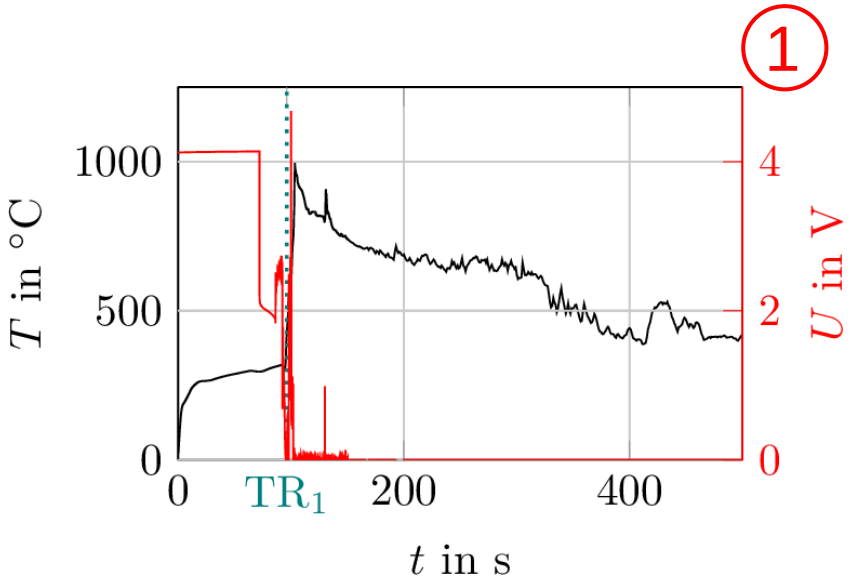


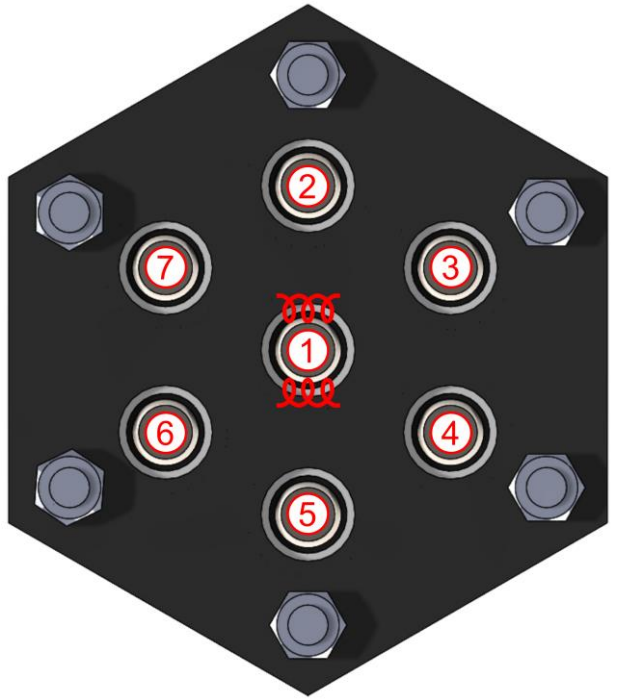


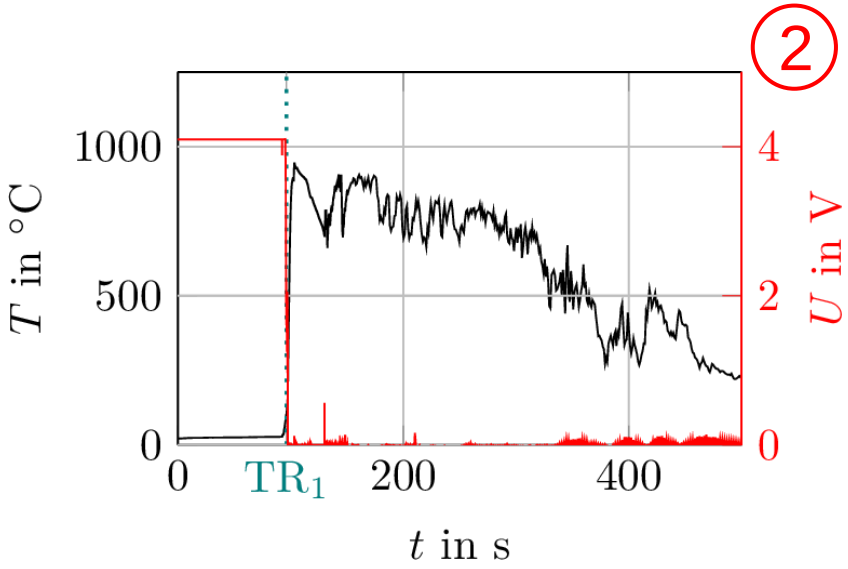
*Thermocouple at cell 6 was broken within the test

Mockup with equal distances

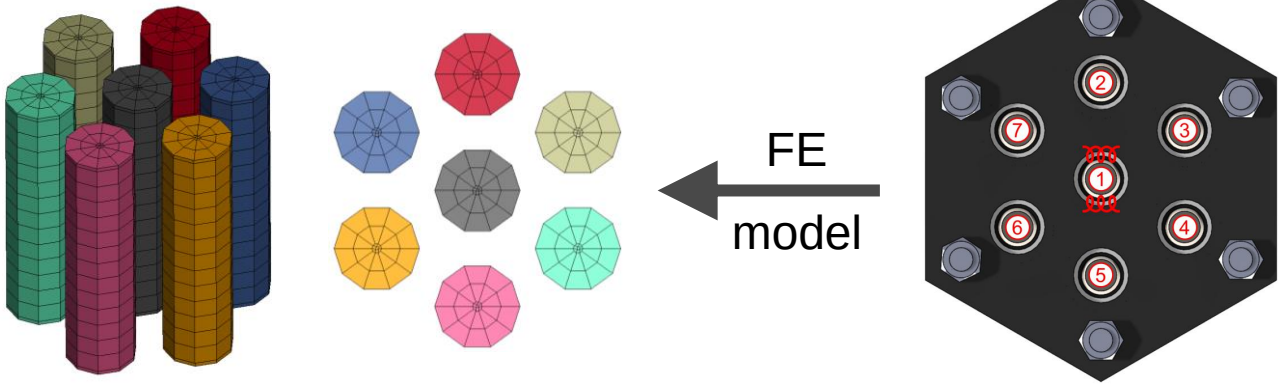
Experimental investigation – behavior of cell 1 and 2

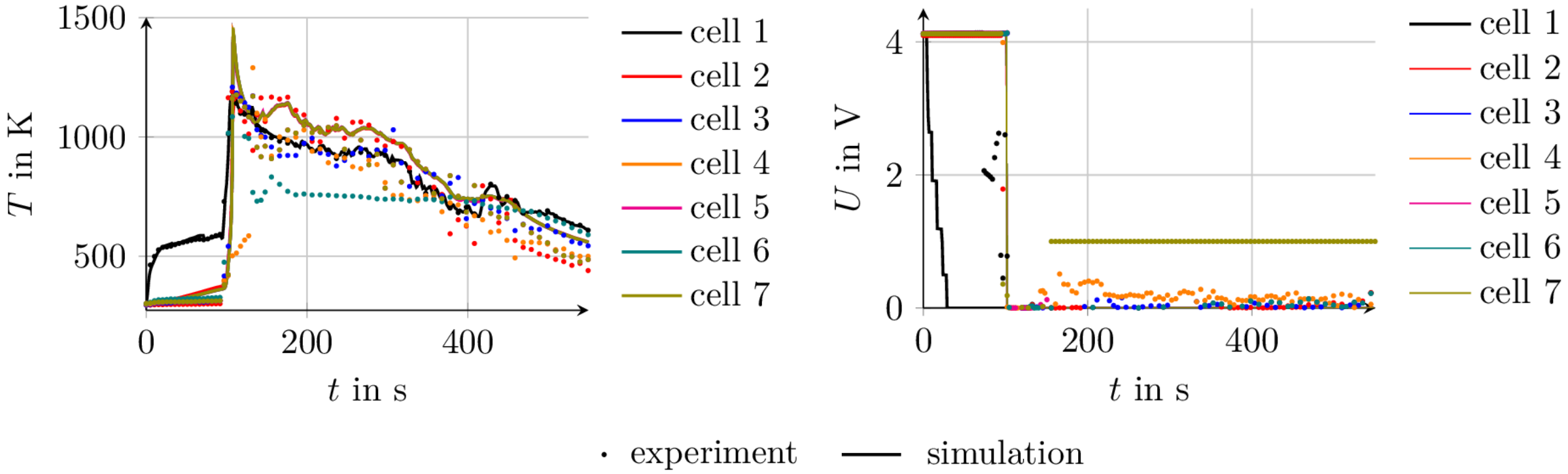






Mockup with equal distances
Simulation results





Mockup with different distances
Experimental investigation

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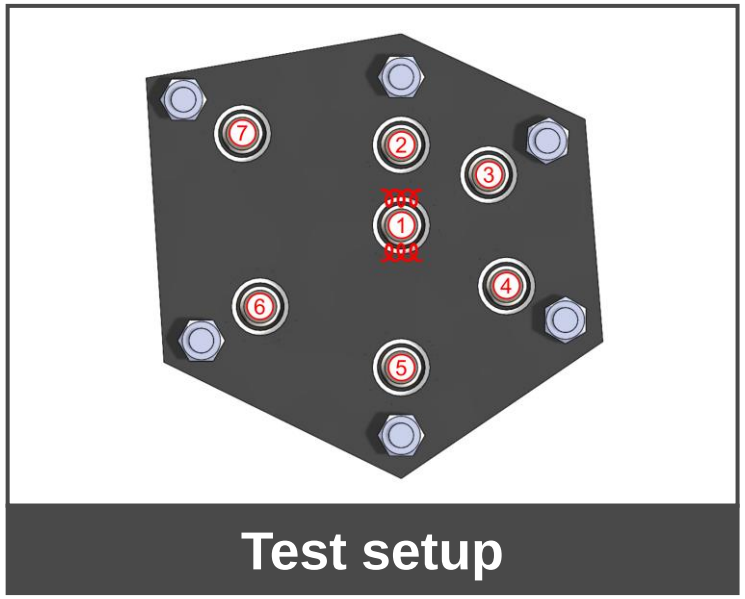
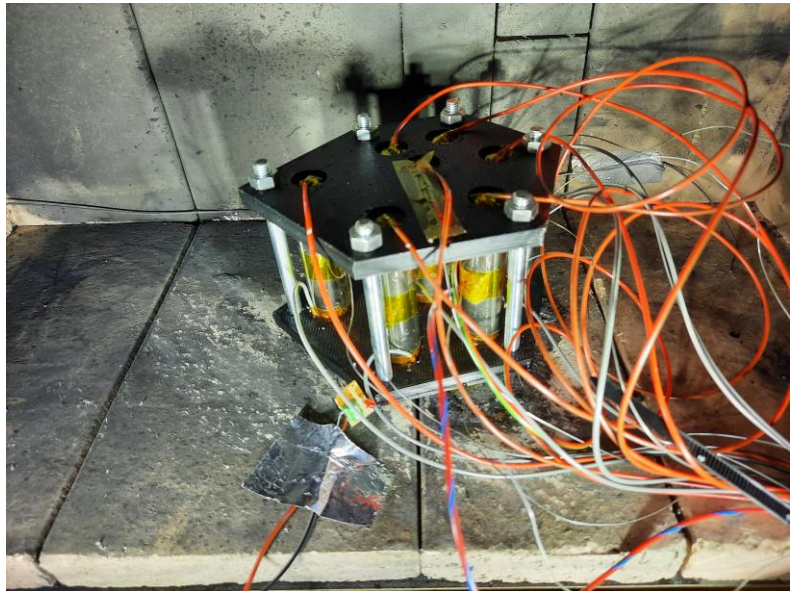


Test setup



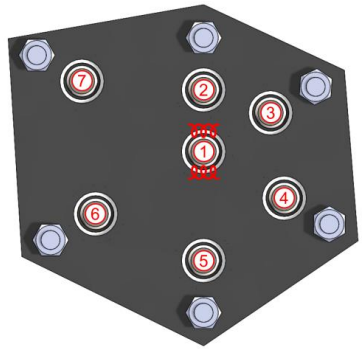
Mockup with different distances
Experimental investigation

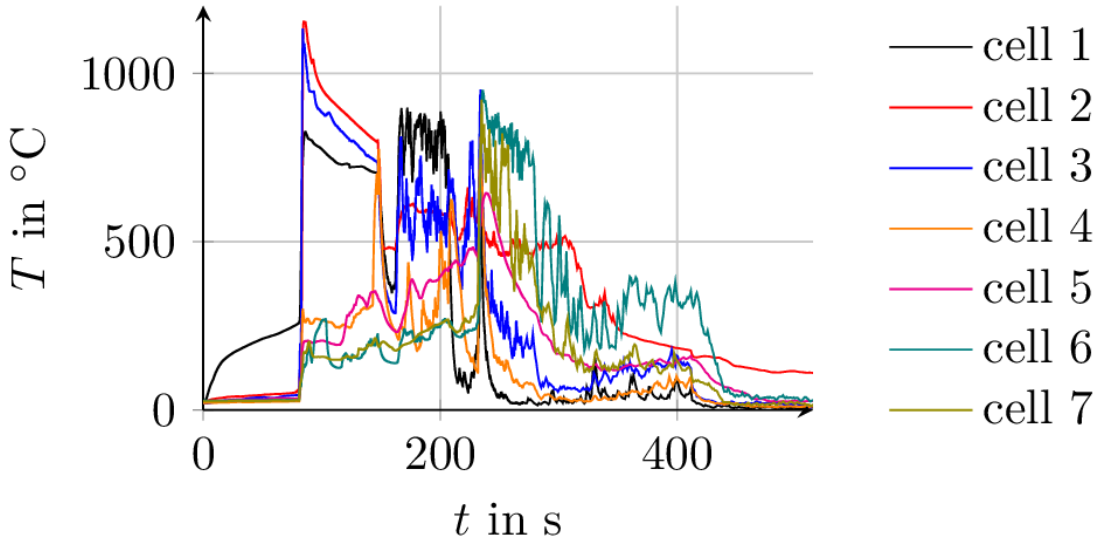
Mock-up with seven 18650 battery cells

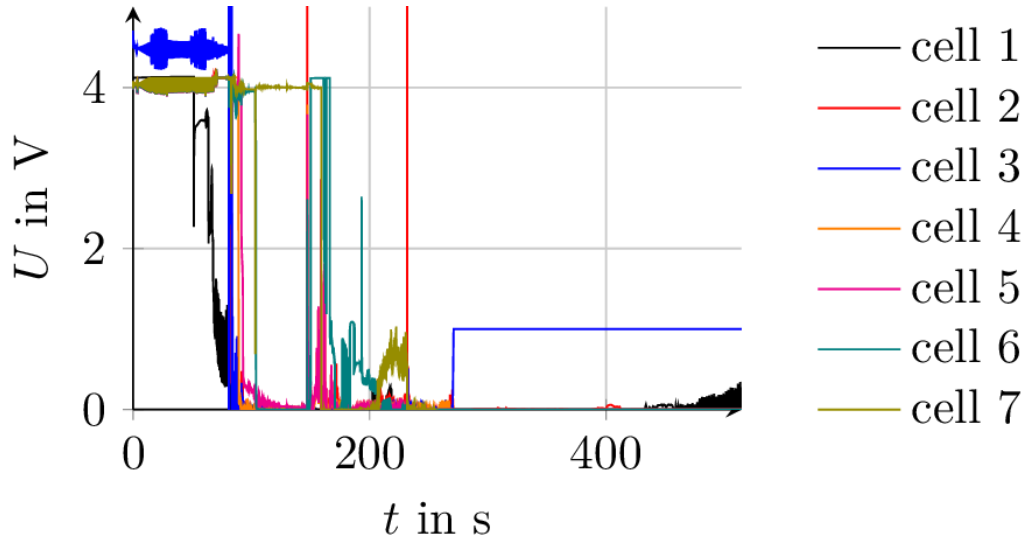
different distances

Mockup with different distances

Experimental investigation – behavior of all cells

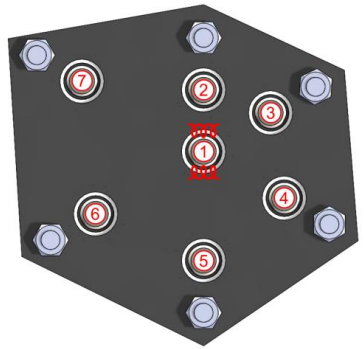


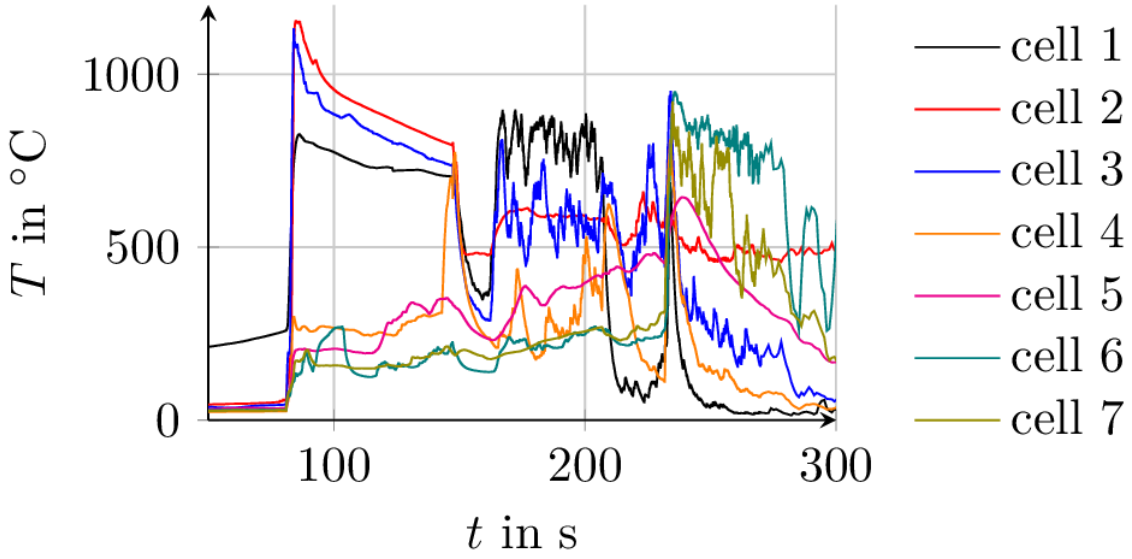


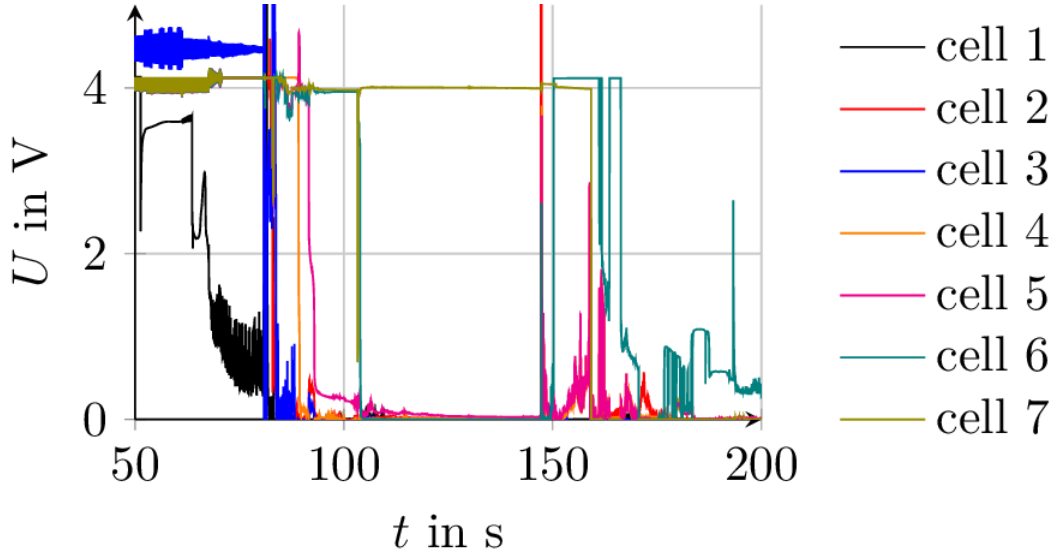


Mockup with different distances

Experimental investigation – behavior of all cells

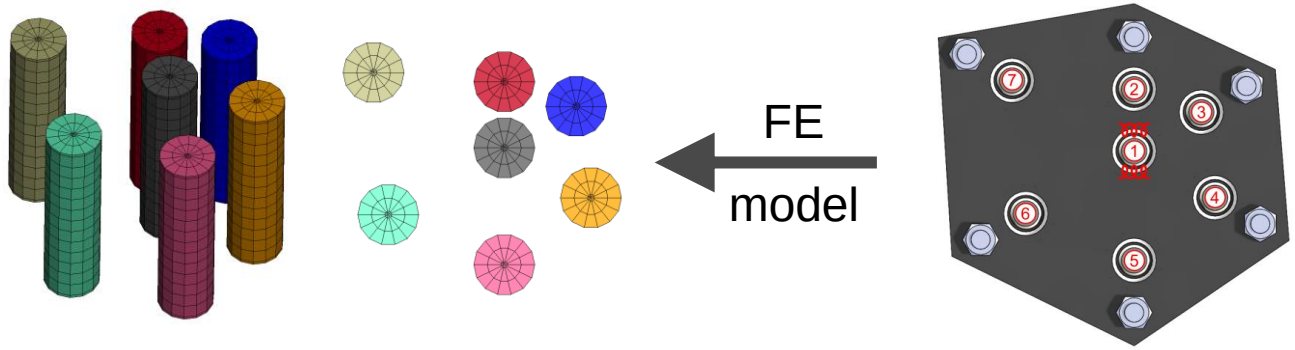


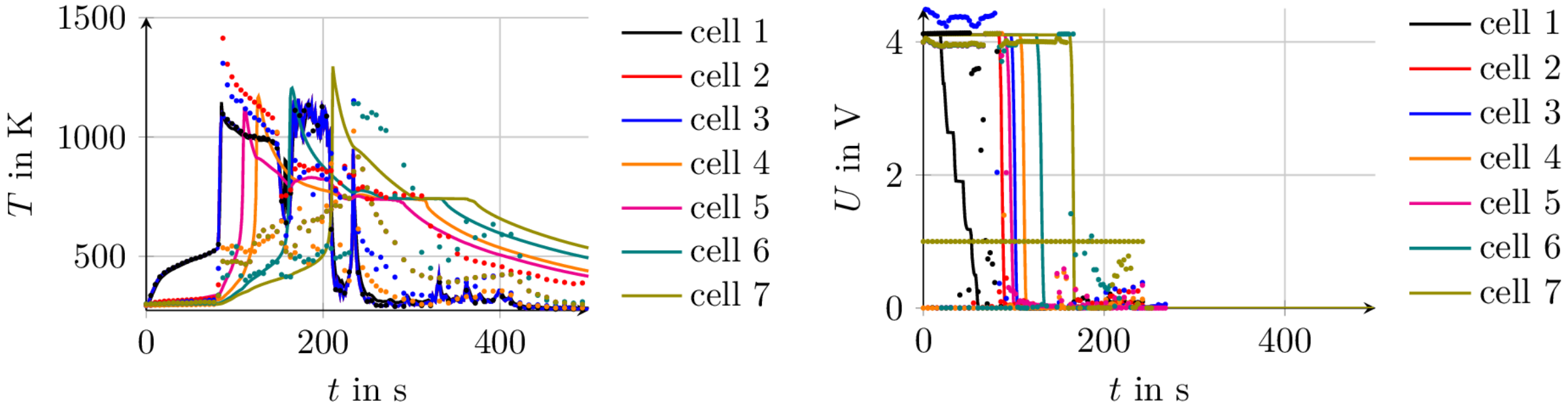




Mockup with different distances

Simulation results





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!

Martin Schwab

martin.schwab@4a.at