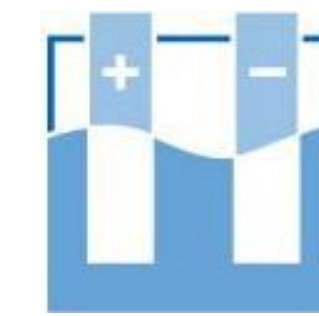




EVS29 Symposium
Montréal, Québec, Canada, June 19-22, 2016

Battery modeling: influence of current collector geometry on the behavior of large lithium-ion pouch cells

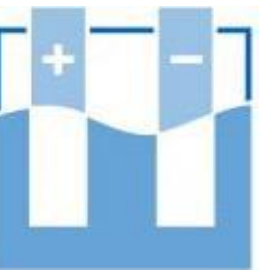
Stephan Kosch, Alexander Rheinfeld, Simon Erhard, Andreas Jossen

Chair of Electrical Energy Storage Technology, Technical University of Munich (TUM),

E-mail address: stephan.kosch@tum.de

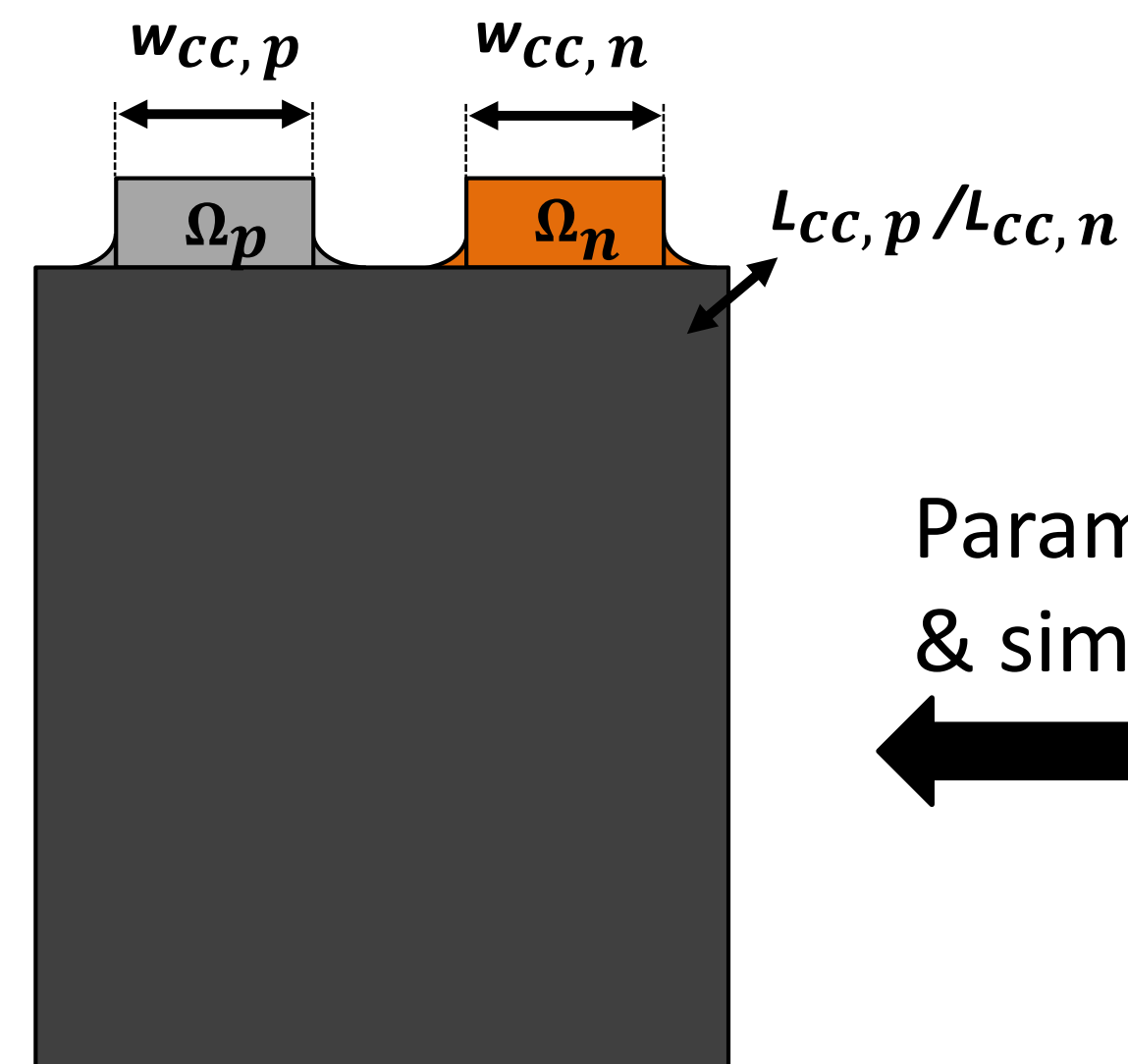


Outline



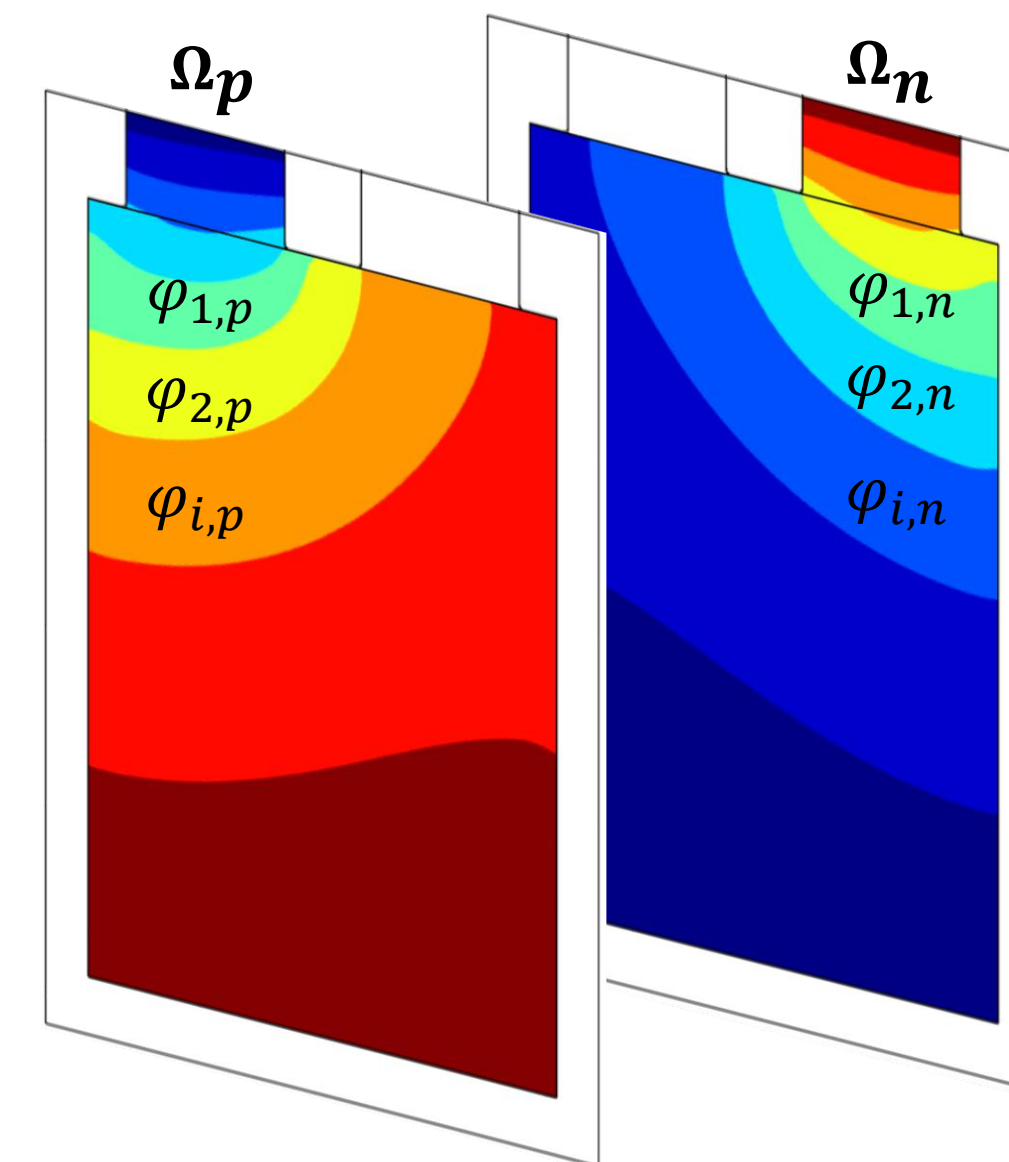
1. Introduction
2. Investigated battery cell
3. Battery cell model
4. Results
5. Conclusion

- Altering geometrical properties of current collectors to optimize the electrical and thermal behavior of a battery cell

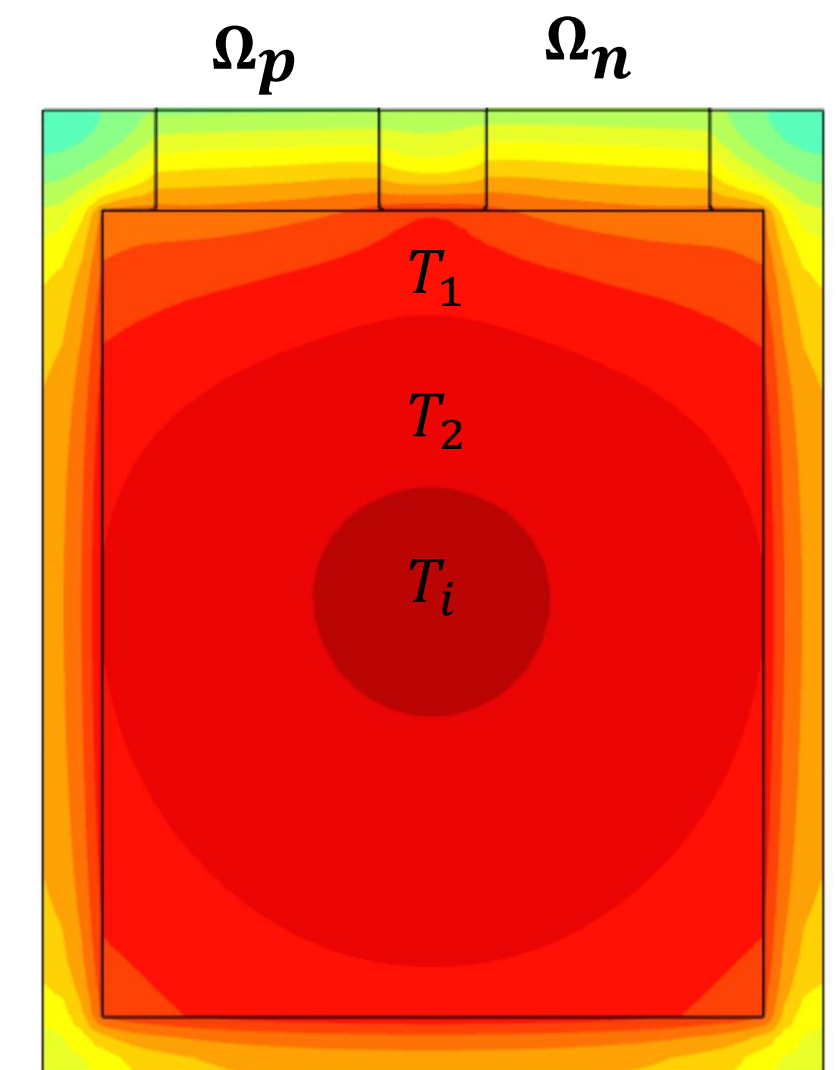


Approximated cell stack with coated current collectors

Parameter variation
& simulation



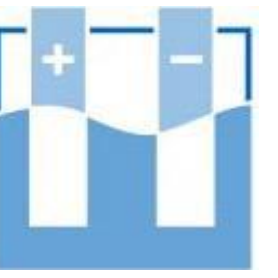
2D electrical model



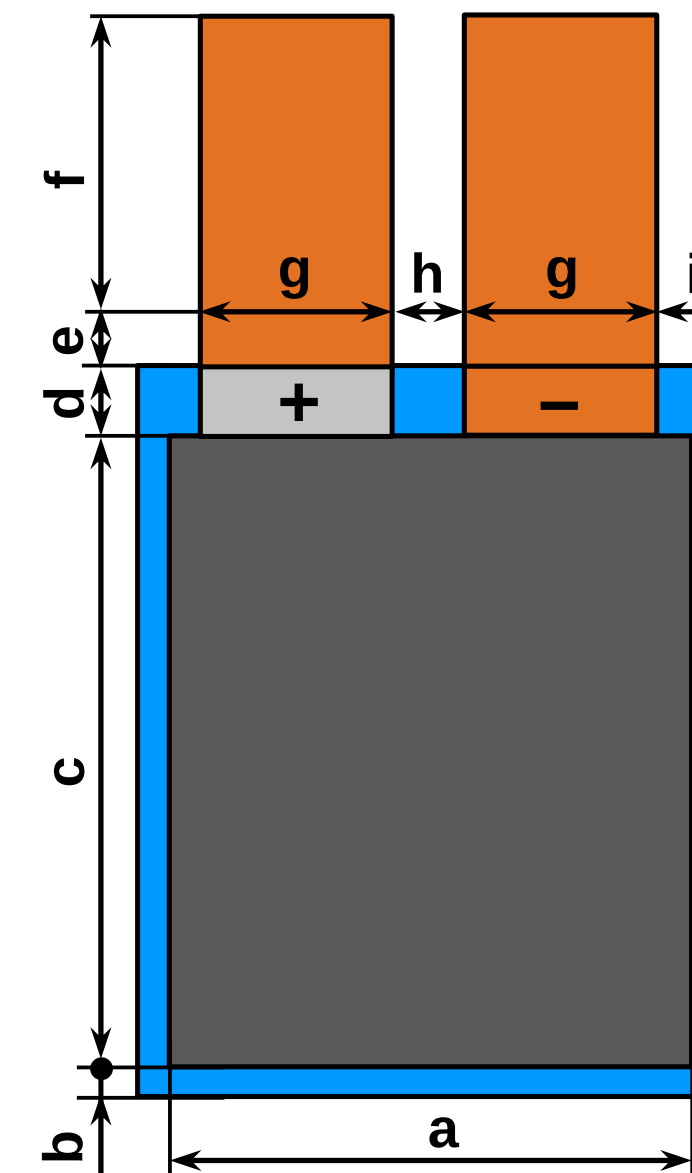
2D thermal model with pouch casing

- Goal: understanding non-uniform state of charge and temperature distribution

Investigated battery cell



- 40 Ah cell with pouch geometry
 - 4C max. discharge rate
 - 1C max. charge rate
- Connectors and lead wires are thick compared to the tabs to ensure small ohmic heating
- Cell is placed into a temperature chamber with controlled air flow



Experimental 40 Ah pouch cell with connectors

- Modeling approach should be simple, accurate and easy to implement
→ polarization modeling approach based on “NTG”

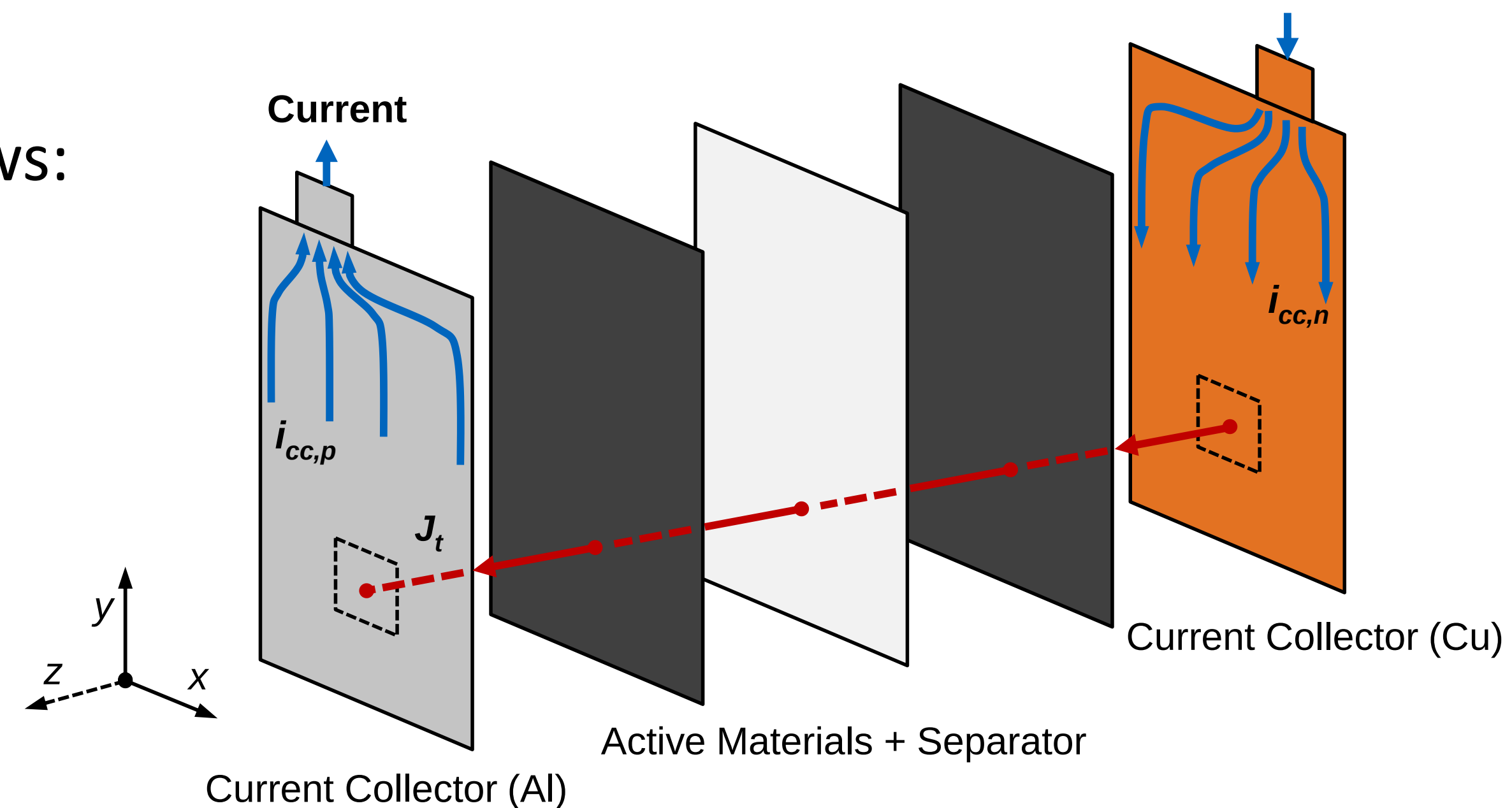
- Realization with conservation laws:

- Charge conservation in current collector tabs:

$$\sigma_{cc,j} \frac{\partial}{\partial x} \left(\frac{\partial \varphi_{cc,j}}{\partial x} \right) + \sigma_{cc,j} \frac{\partial}{\partial y} \left(\frac{\partial \varphi_{cc,j}}{\partial y} \right) = 0$$

- Continuity of charge between current collectors:

$$\sigma_{cc,j} \frac{\partial}{\partial x} \left(\frac{\partial \varphi_{cc,j}}{\partial x} \right) + \sigma_{cc,j} \frac{\partial}{\partial y} \left(\frac{\partial \varphi_{cc,j}}{\partial y} \right) = \frac{n_j \cdot J_t}{0.5 \cdot L_{cc,j}}$$

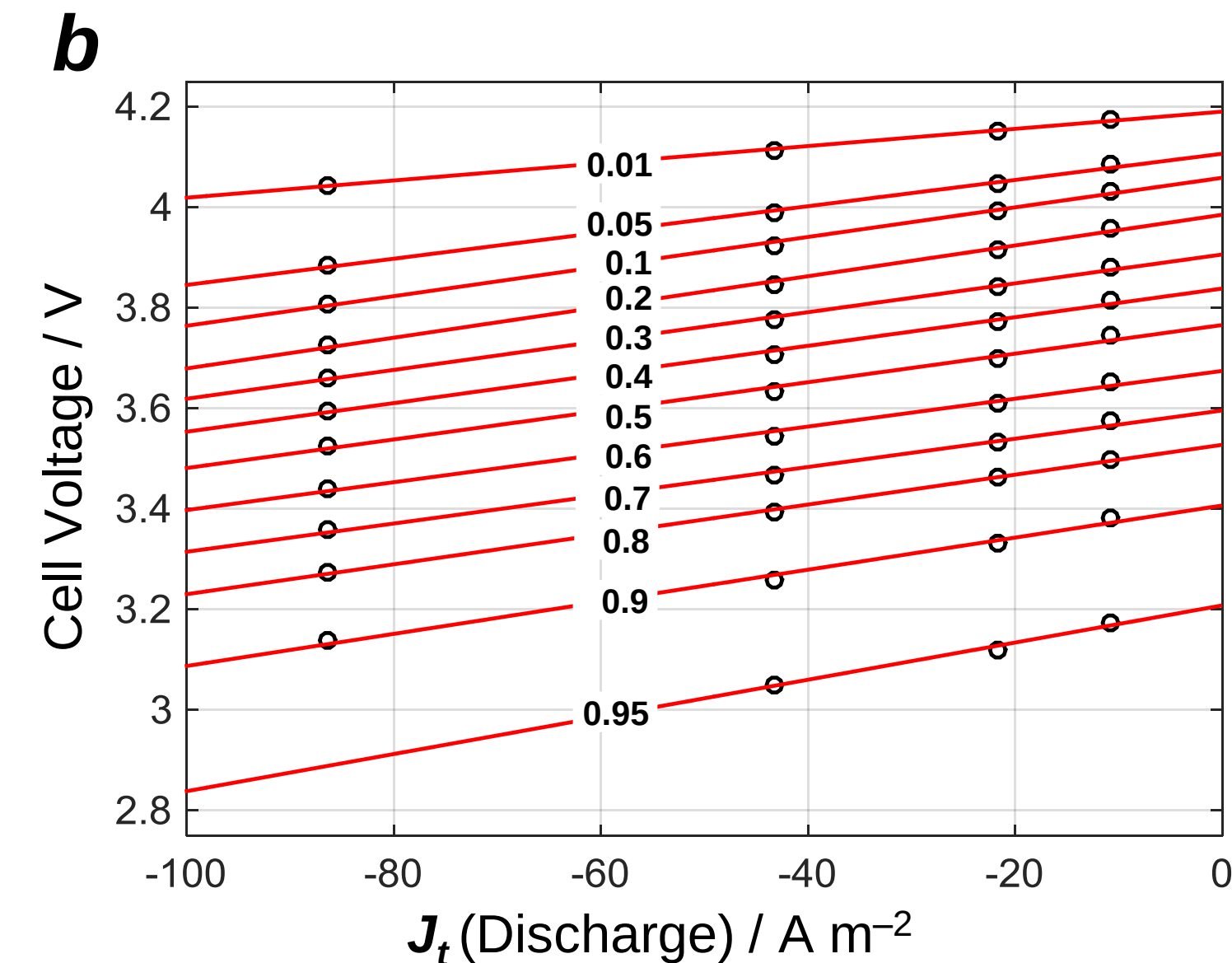
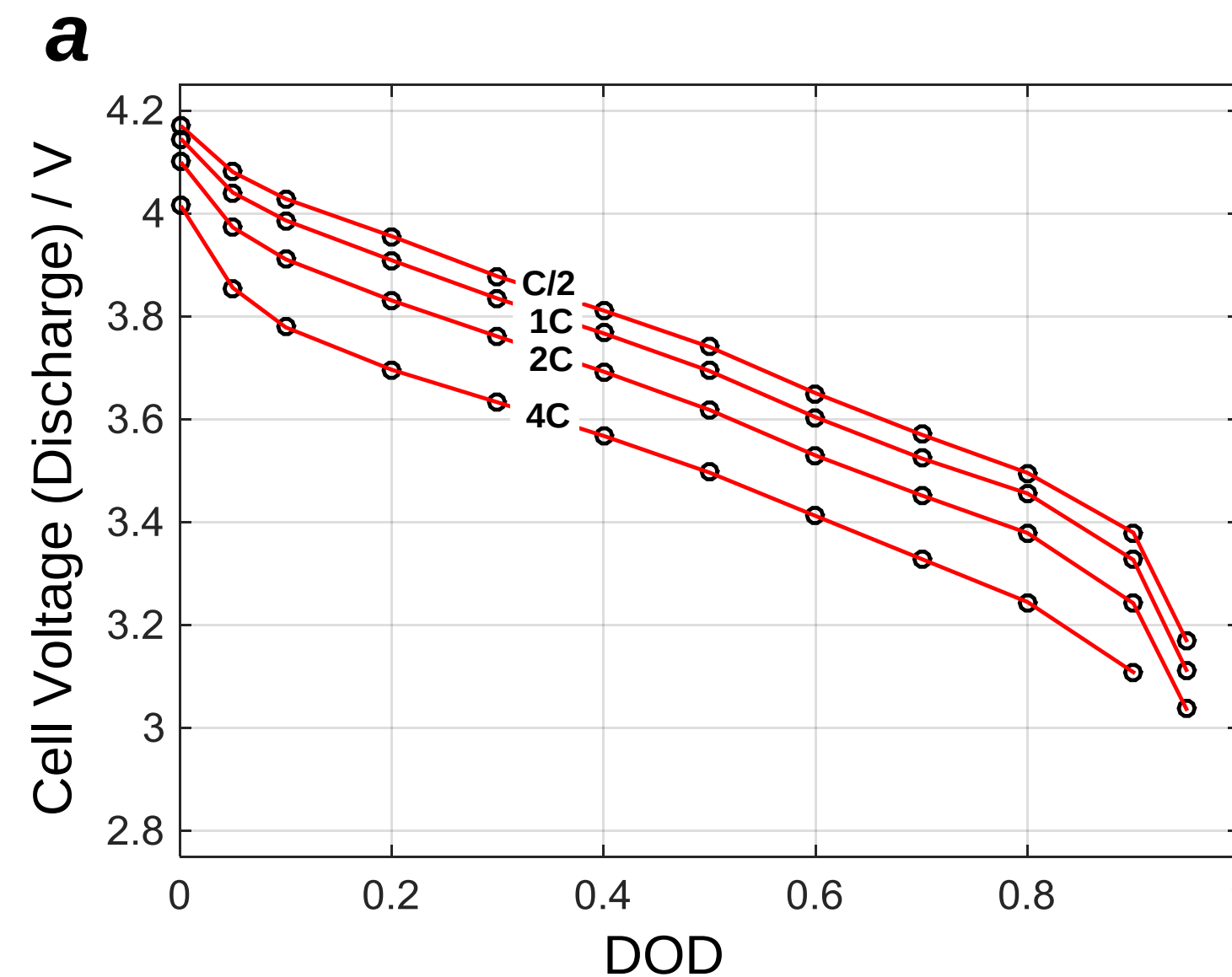


Schematic of simplified cell assembly

- Current transferred through the separator:

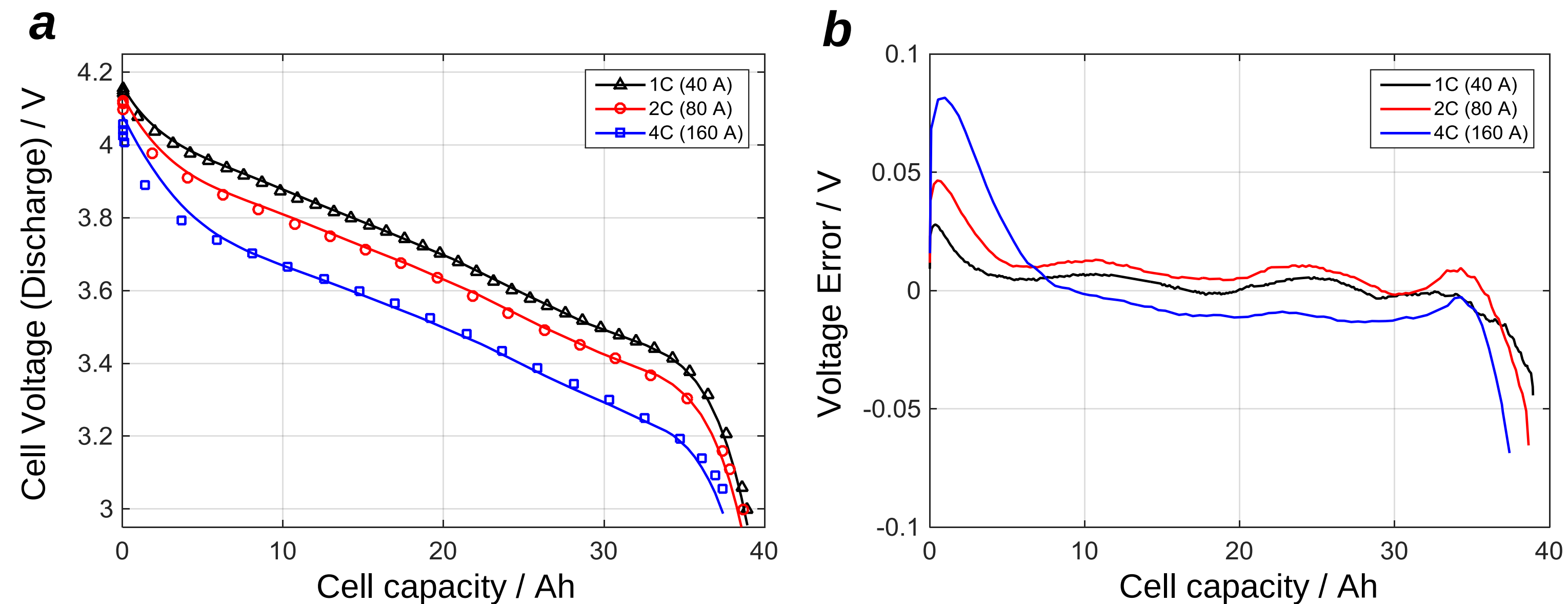
$$J_t(x, y) = -Y_{s,lin}(x, y) \left(\varphi_{cc,p}(x, y) - \varphi_{cc,n}(x, y) - U_{ocv,lin}(x, y) \right)$$

- Here $Y_{s,lin}(x, y)$ approximates the non-linear current-potential characteristic of the cell



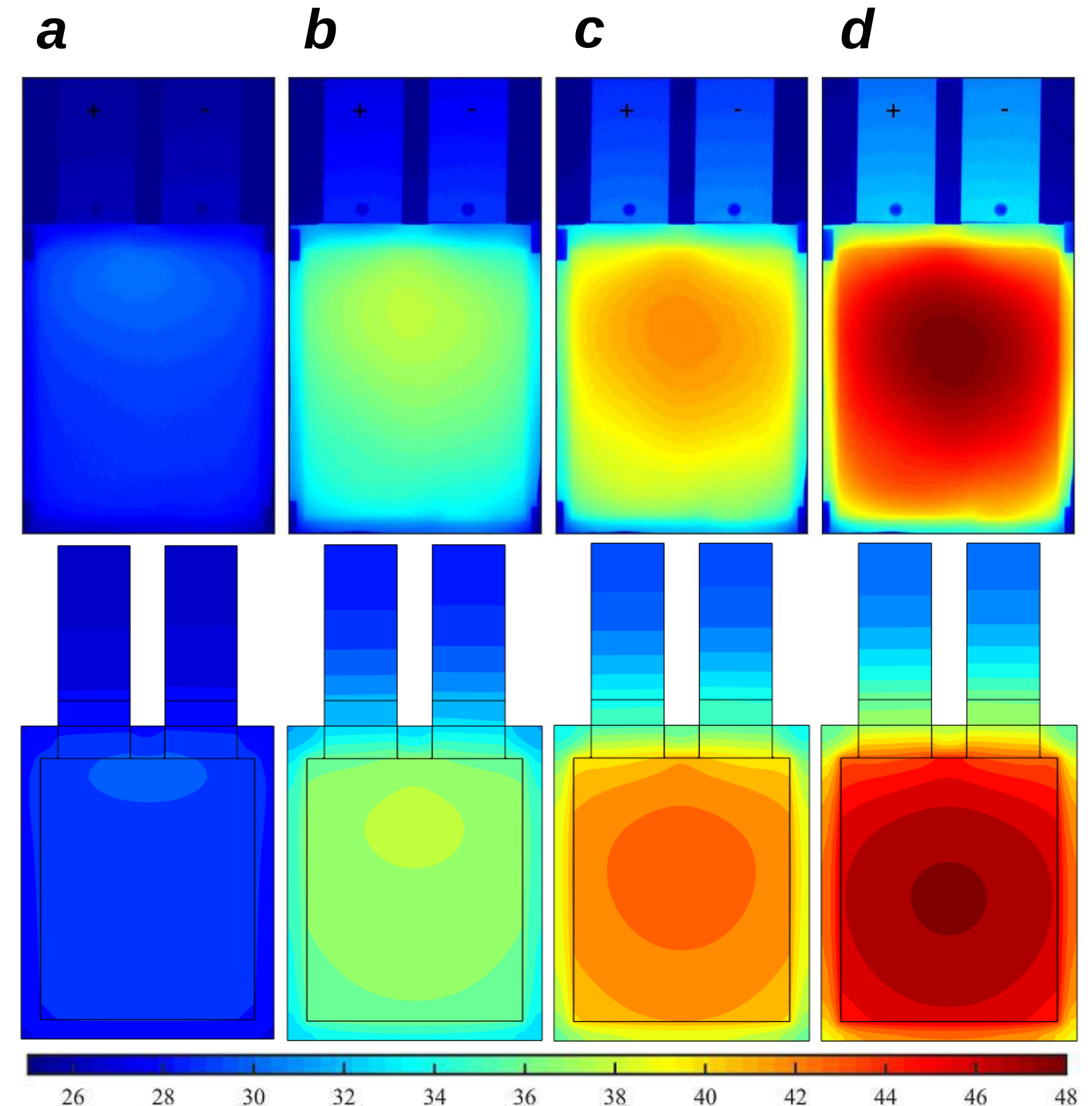
a) Measured voltage response b) Linearized current-potential characteristic

- Electrical validation:
 - Voltage error between 15% and 85% DOD is < 20 mV
 - Approximation error at high discharge rates at the beginning and the end of the discharge process



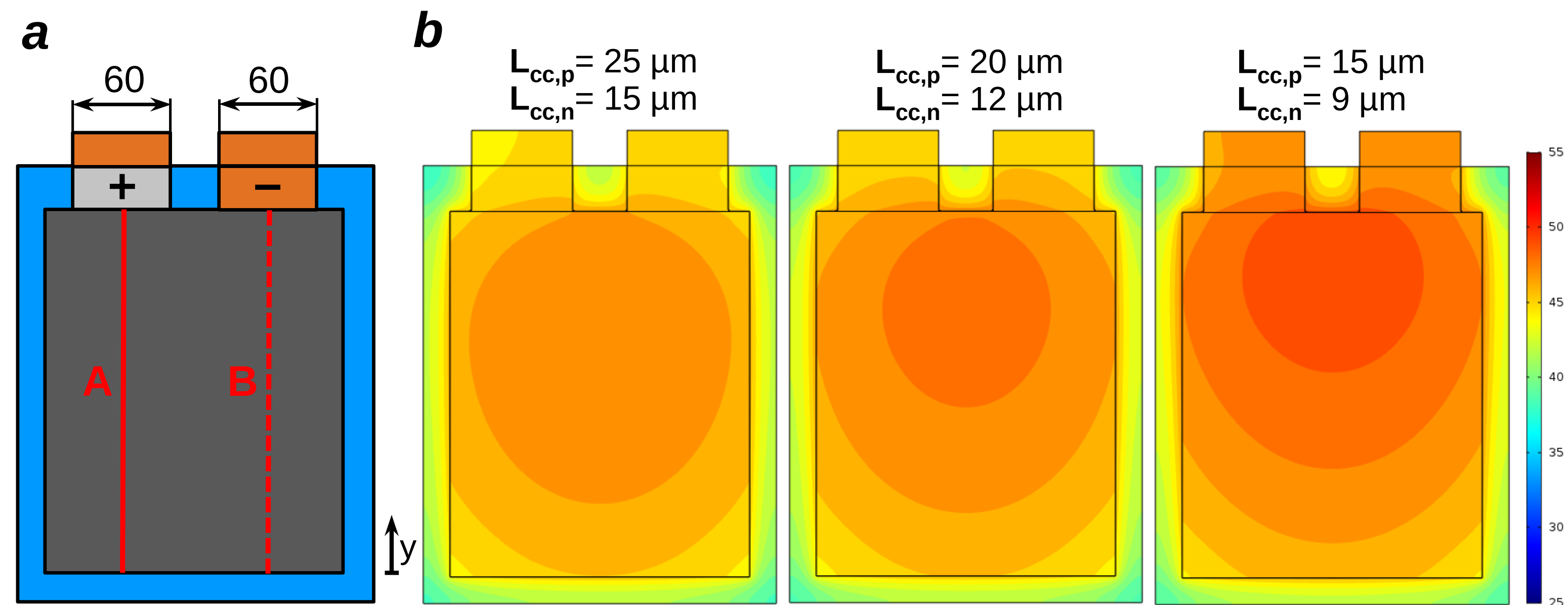
a) Measured and simulated voltage b) Voltage error

- Thermal validation with thermal infrared camera at
 - a) 12.5% DOD
 - b) 38.5% DOD
 - c) 65% DOD
 - d) 93.5% DOD
- Contours in simulation indicate 1K temperature difference

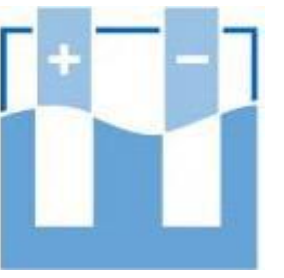


Measured (top) and simulated (bottom) temperature

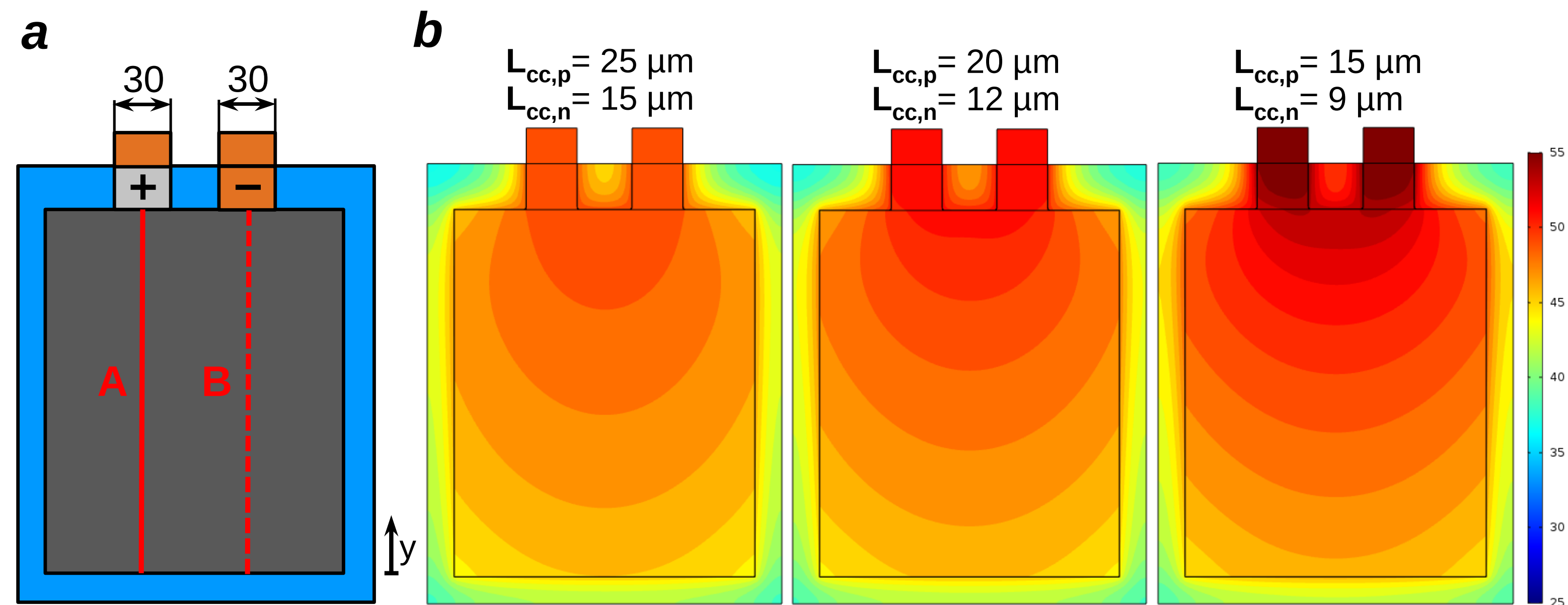
- Simulated case studies
 - Current collector thickness ratio is constant, 3 different ratios
 - Connectors are neglected
 - Design case I: 60 mm tab size, Design case II: 30 mm tab size



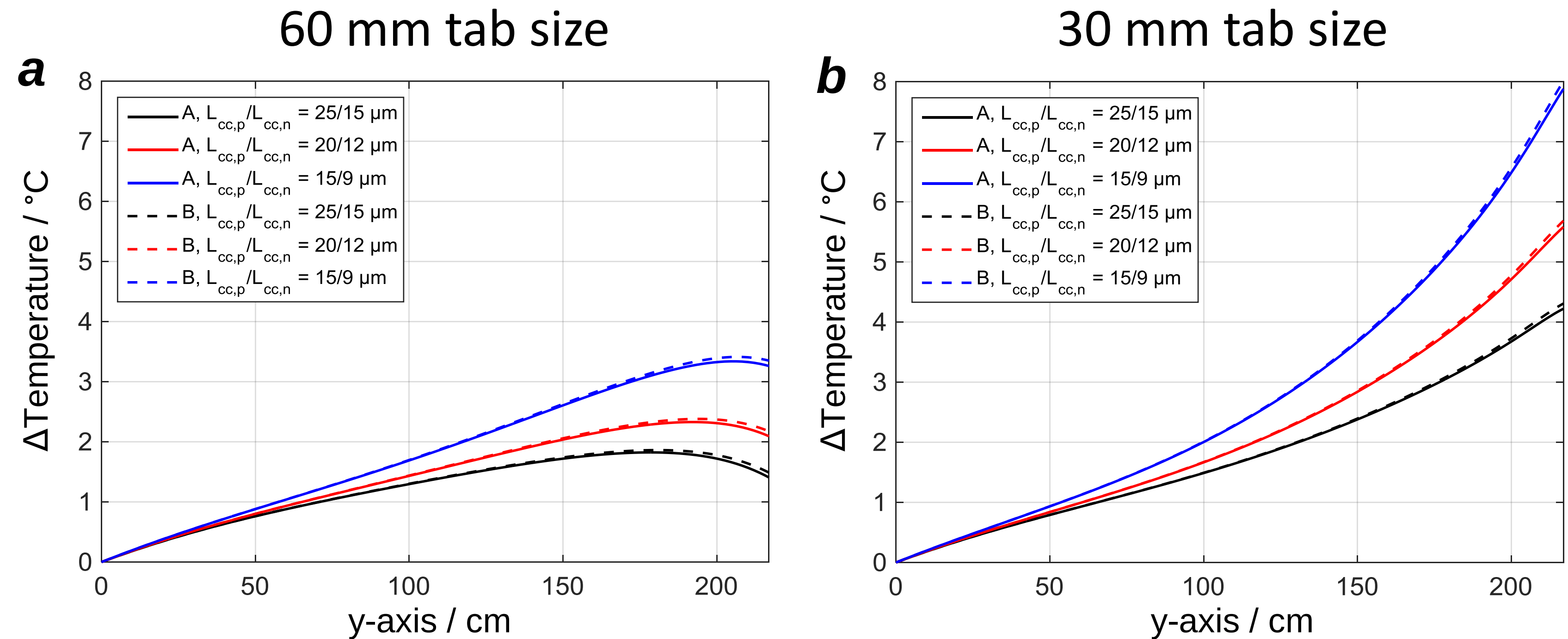
Design case I: simulated temperature response at the end of 4C discharge



- Higher temperature peak observable due to smaller tab size, up to 5K increase compared to 60 mm tab size
- Temperature peak is moving to the tab region

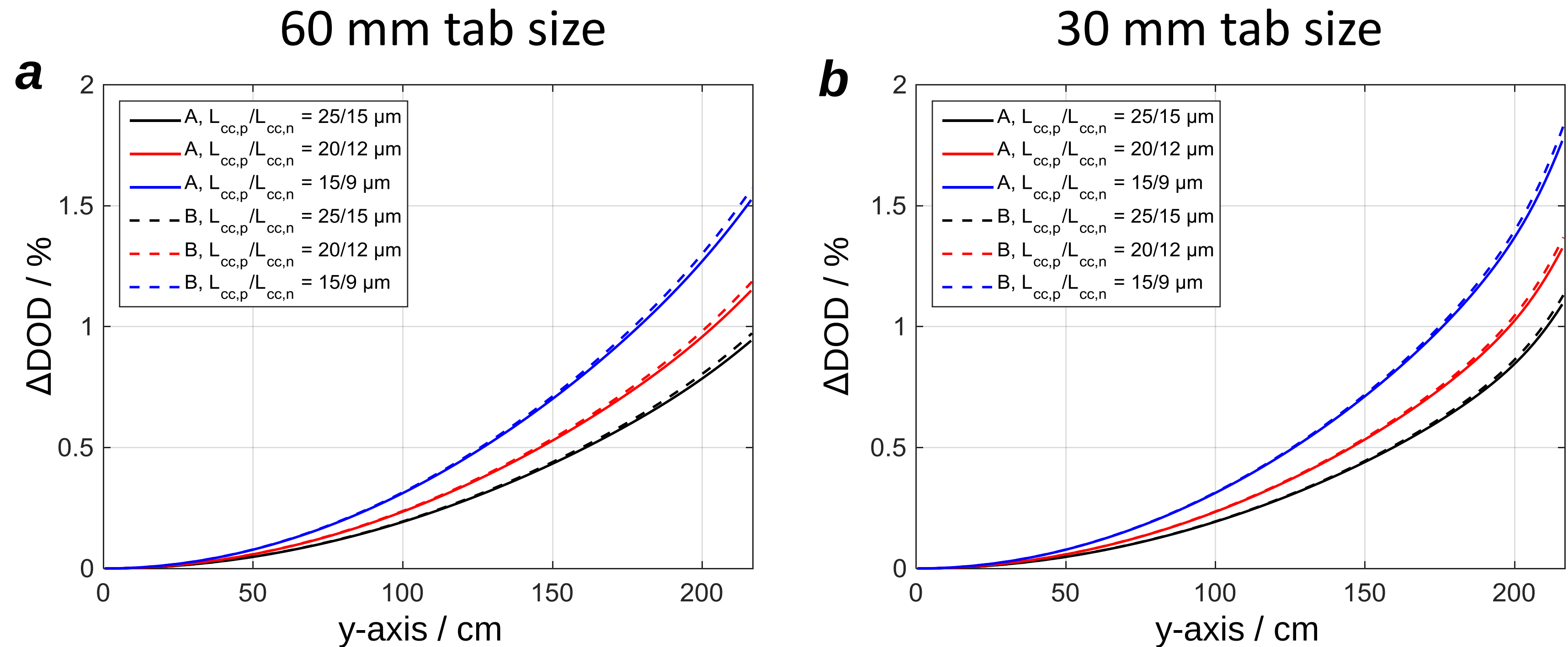


Design case II: simulated temperature response at the end of 4C discharge



Comparison: Temperature non-uniformity at 50% DOD (tabs at 230 cm)

→ Influence of tab size on temperature non-uniformity **significantly higher** than current collector thickness



Comparison: DOD non-uniformity at 50% DOD (tabs at 230 cm)

→ Influence of tab size on DOD non-uniformity **significantly smaller** than current collector thickness

- Easy to implement modeling approach
 - Low parameterization effort (charge/discharge data), low computational time
 - High accuracy for constant current loads (and even for dynamic current loads)
- Current collector thickness vs. tab size
 - Tab size has significantly higher influence on temperature distribution
 - Current collector thickness has higher influence on non-uniform SOC/DOD distribution
- Analysis shows that smaller current collector thickness should be considered
 - Impact on temperature and SOC/DOD distribution relatively small
 - Specific energy density can be increased (due to less inactive material)
 - Cost reduction (less material)

Battery modeling: influence of current collector geometry on the behavior of large lithium-ion pouch cells

Stephan Kosch, Alexander Rheinfeld, Simon Erhard, Andreas Jossen

Chair of Electrical Energy Storage Technology, Technical University of Munich (TUM),

E-mail address: stephan.kosch@tum.de