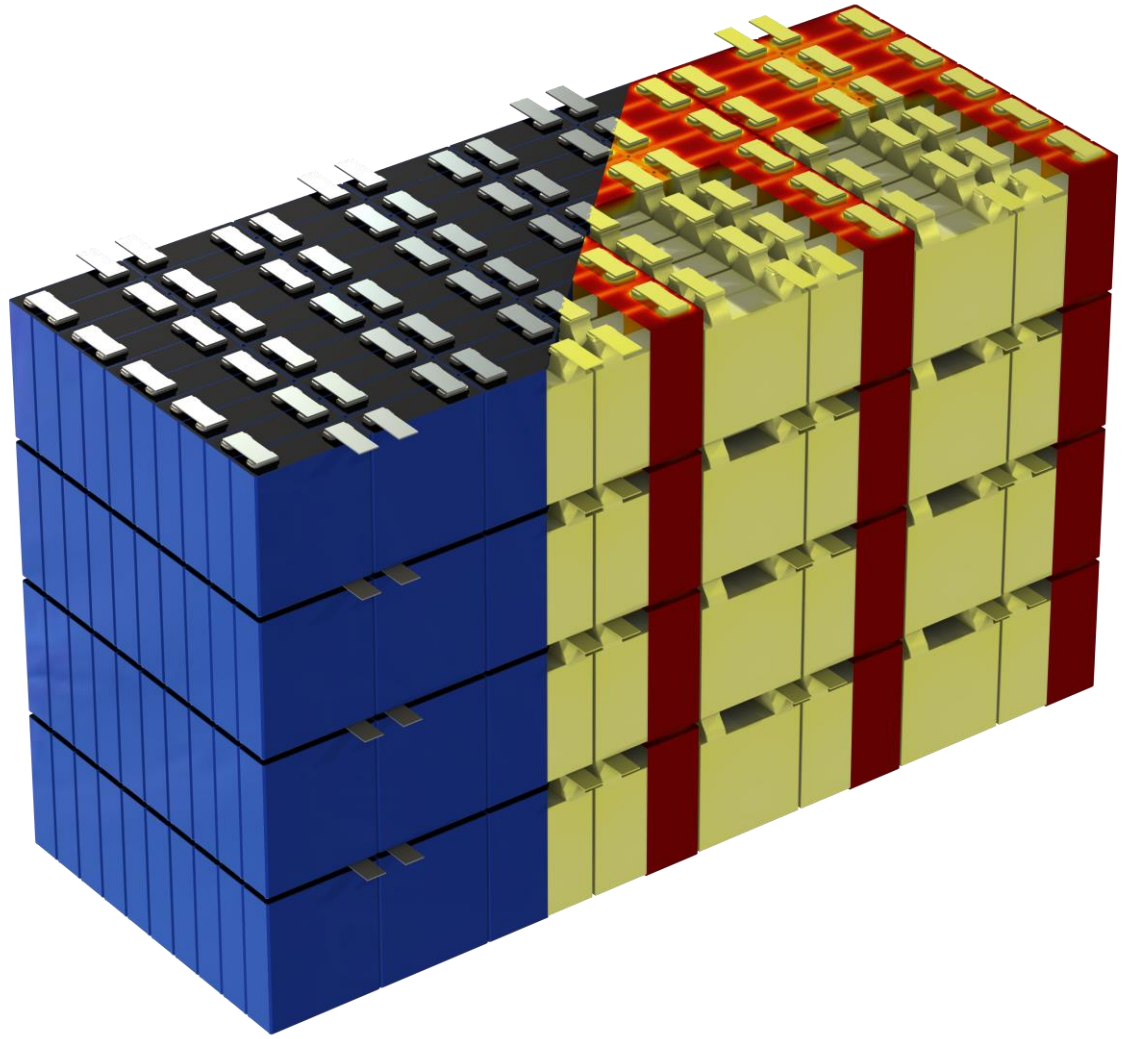

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Novel Method For Predicting Lifetime Degradation Of Battery Packs Using COMSOL Surrogate Models

By André G. Steckel, Thomas Bisgaard, Martin Refslund Nielsen

Introduction

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André G. Steckel

Modelling specialist

Email: ags@resolvent.dk

- Batteries
- Fuel / electrolysis cells
- Microfluidics
- Acoustics
- Acoustofluidics
- COMSOL apps
- Reduced order models
- Magneto statics
- Electromagnetic induction
- Medical diagnostics equipment

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Medical diagnostics equipment

Invited talk: Electrochemistry II

Impact of Battery Operation and Manufacturing Process on Battery Performance over Lifetime

Wednesday 3:30 p.m.

Thomas Bisgaard

Email: tb@resolvent.dk

Keynote

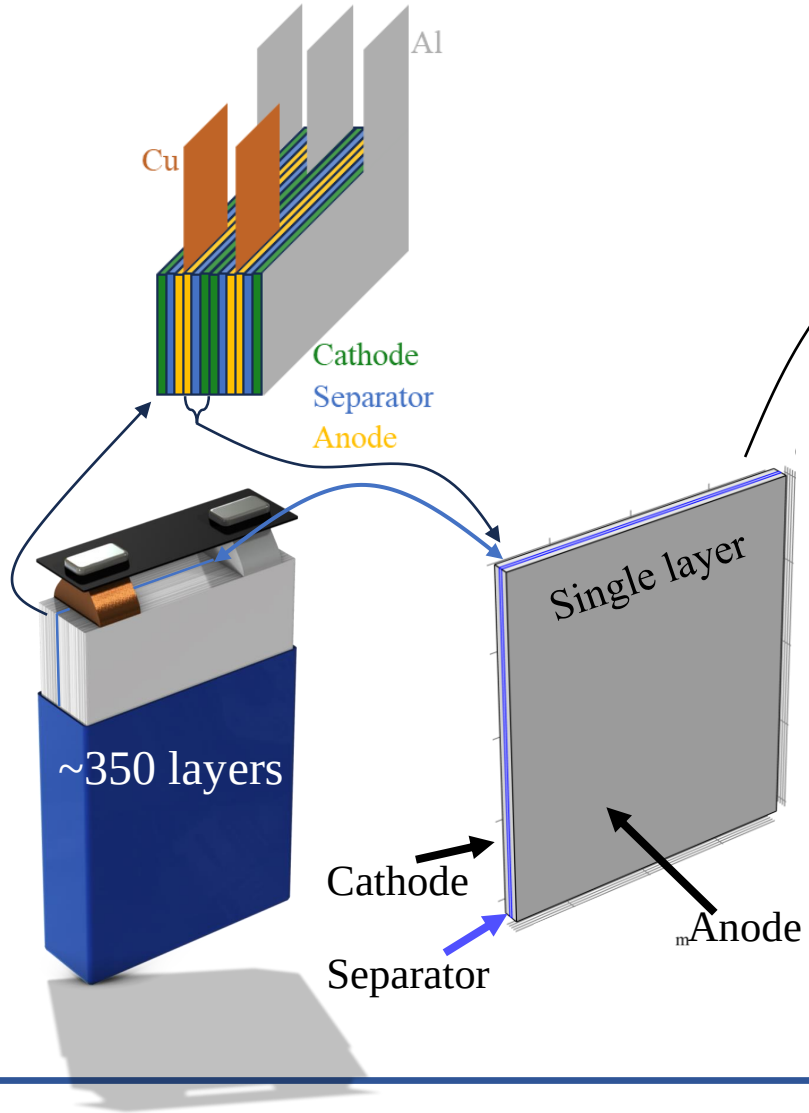
Battery App Optimizing Lifetime and Robustness for Volvo

Thursday 10:30 a.m.

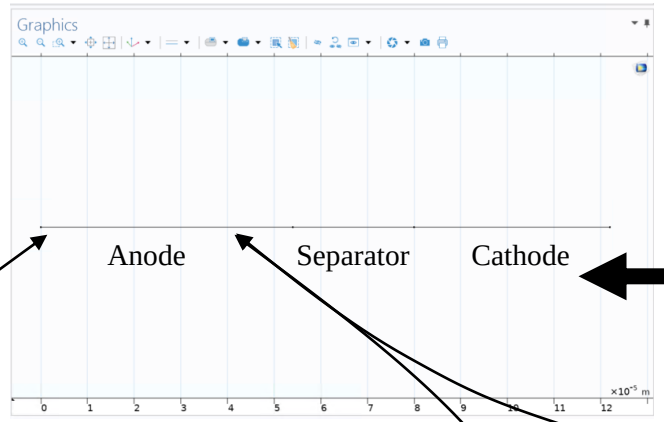
Martin Refslund Nielsen

Email: mrn@resolvent.dk

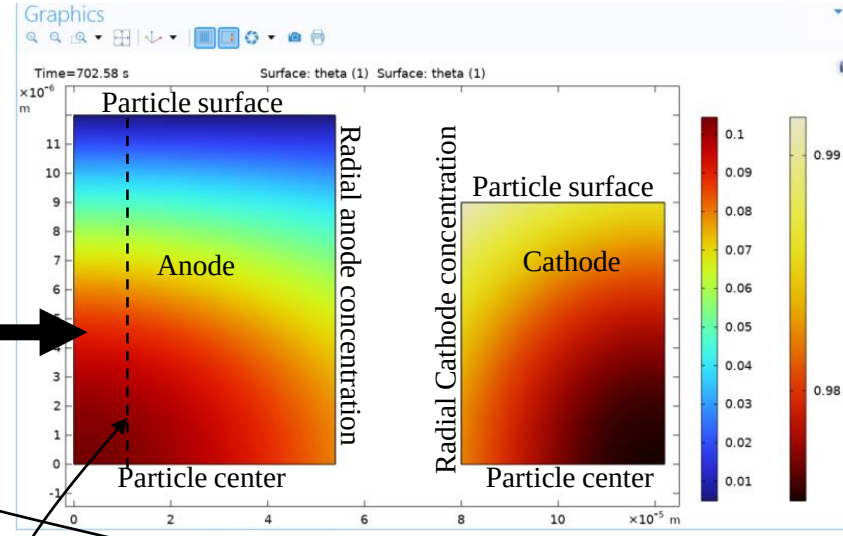
Battery chemistry



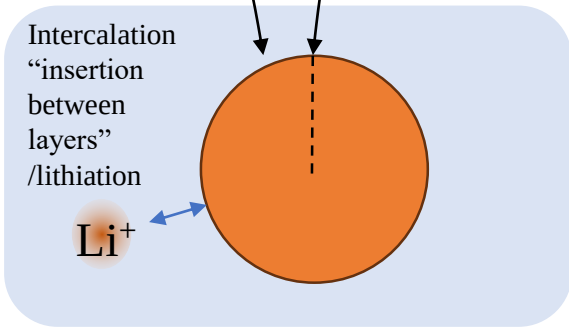
1D Cell chemistry



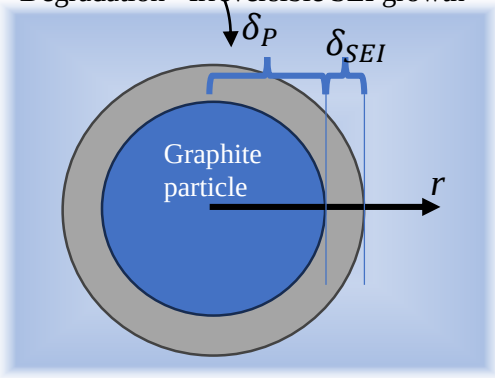
2D Radial chemistry



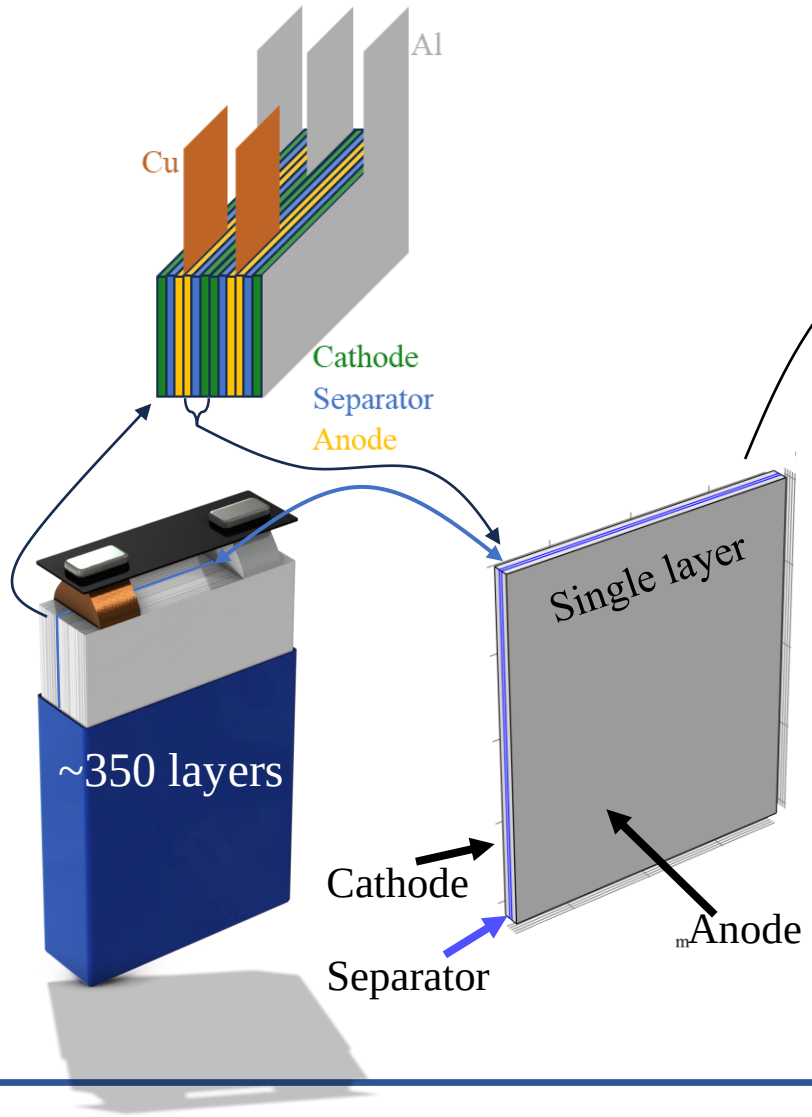
Spherical Electrode Particles



Degradation - Irreversible SEI growth

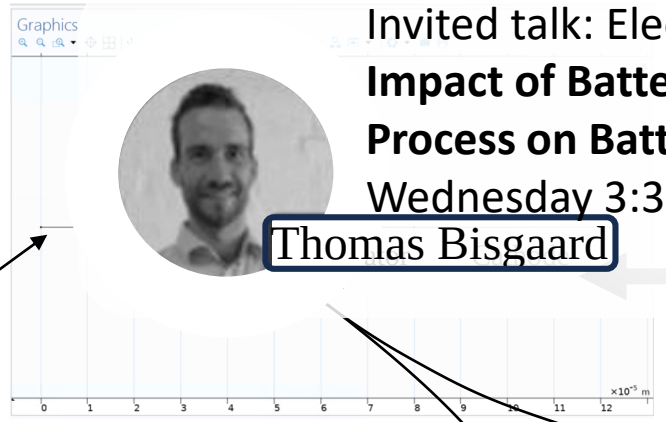


Battery chemistry



1D Cell chemistry

2D Radial chemistry

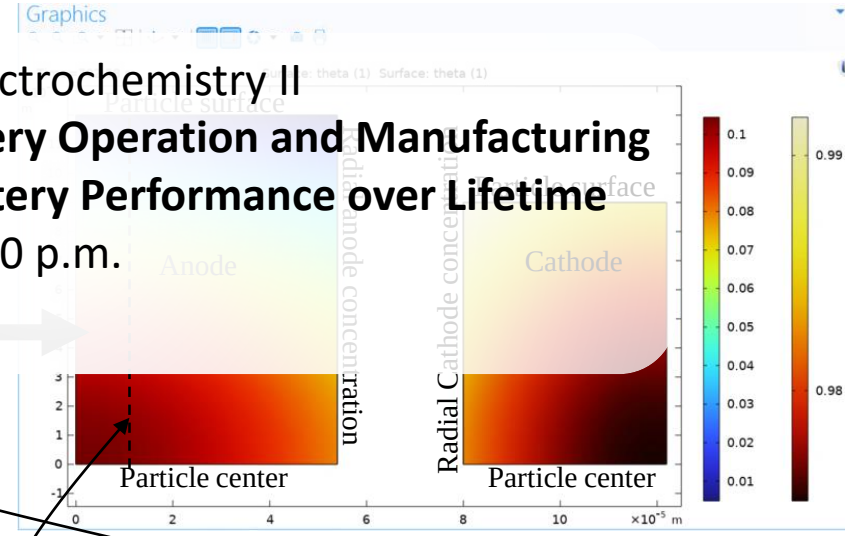


Invited talk: Electrochemistry II

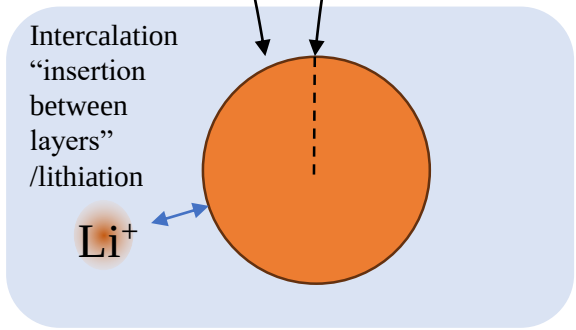
Impact of Battery Operation and Manufacturing Process on Battery Performance over Lifetime

Wednesday 3:30 p.m.

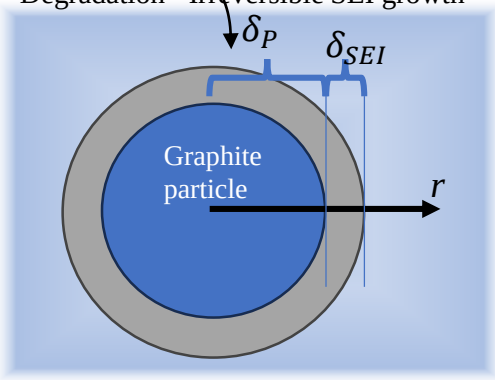
Thomas Bisgaard



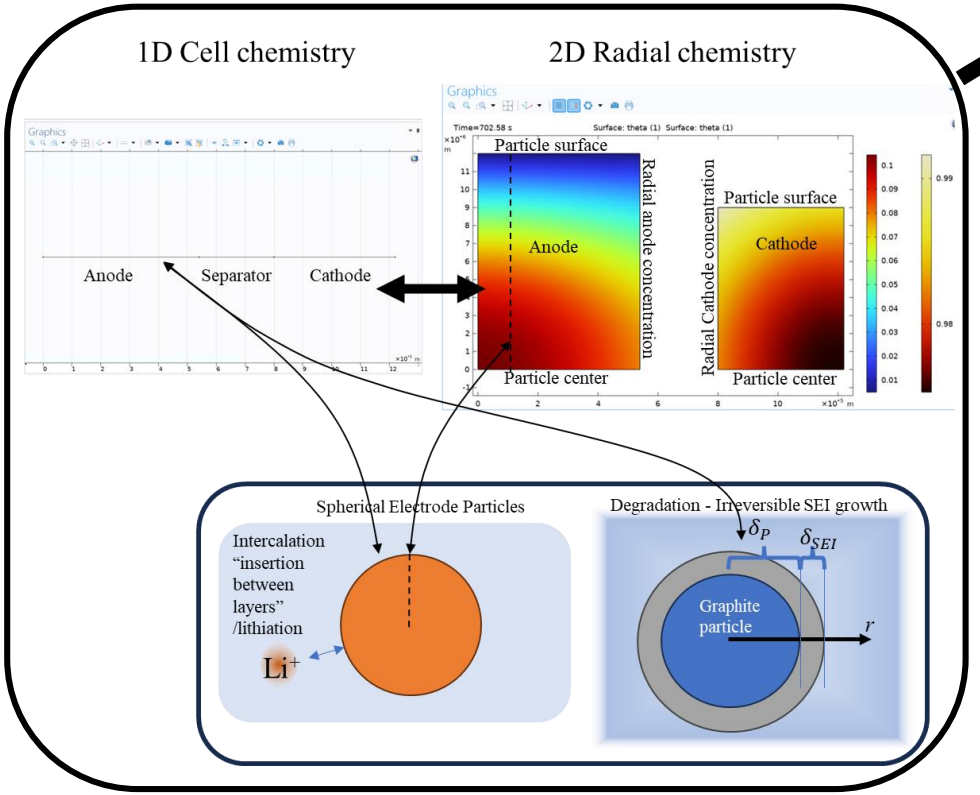
Spherical Electrode Particles



Degradation - Irreversible SEI growth



Battery chemistry to surrogate modelling



Surrogate modelling

Generate parameters

1D + 2D

Latin Hypercube Sampling:
Temperature
Current (Record voltage)
SOC (Transient simulation)
SEI layer thickness

Train Deep Neural Networks for Predictions

Surrogate modelling

Generate parameters

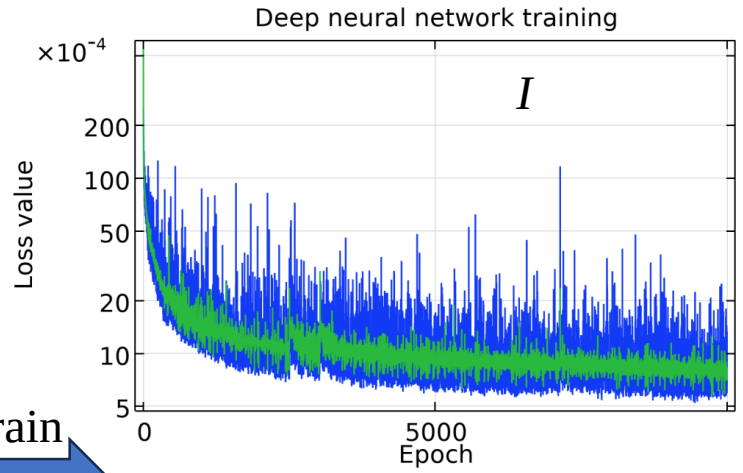
1D + 2D

Latin Hypercube Sampling:
Temperature
Current (Record voltage)
SOC (Transient simulation)
SEI layer thickness

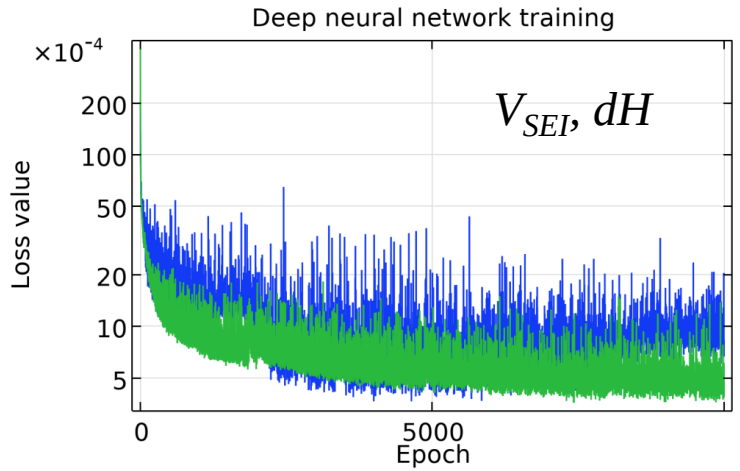
Run

LHS

Train



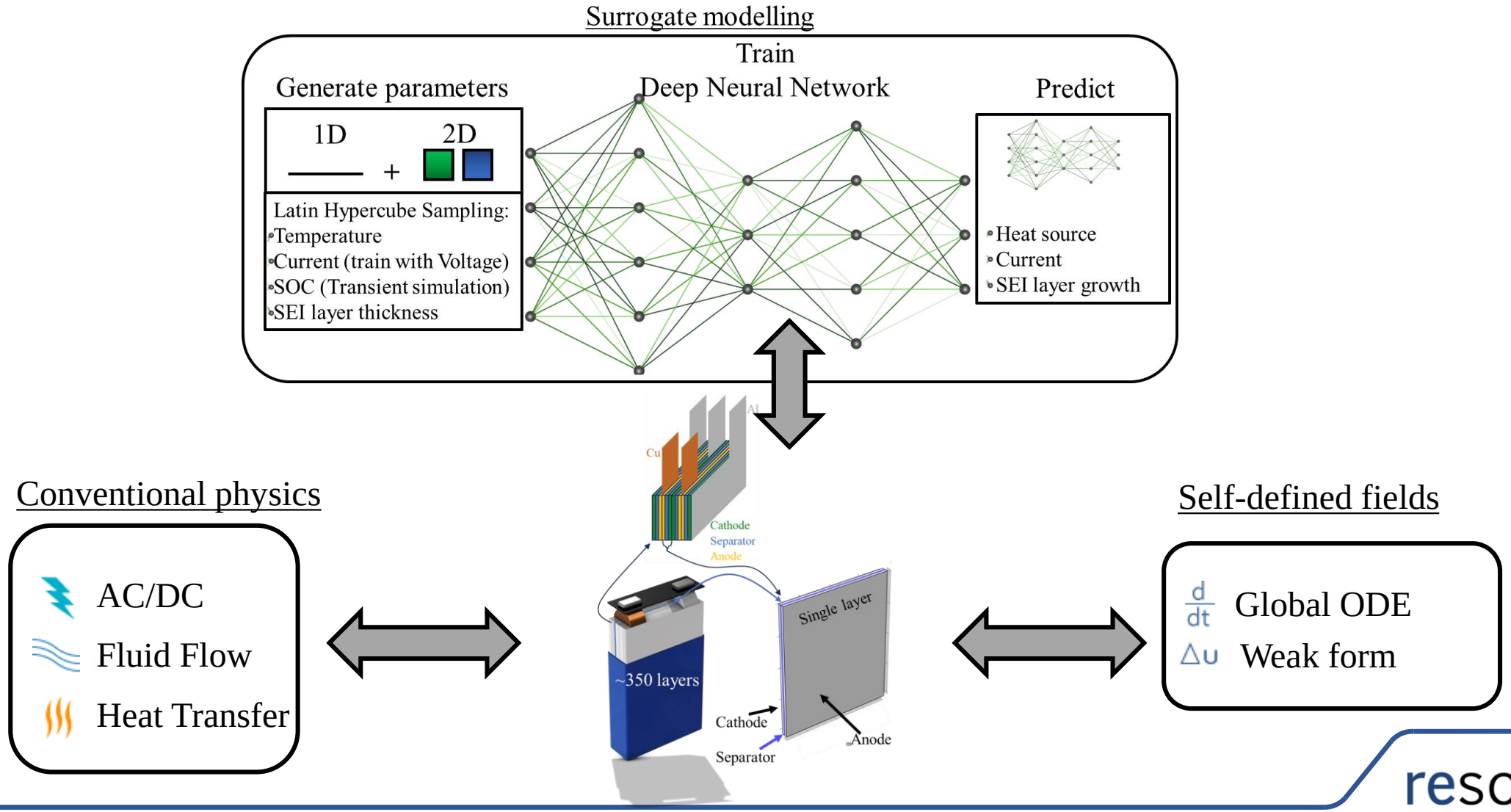
$$Ave\left(\left|\frac{I - DNN_I}{I}\right|\right) = 0.18\%$$



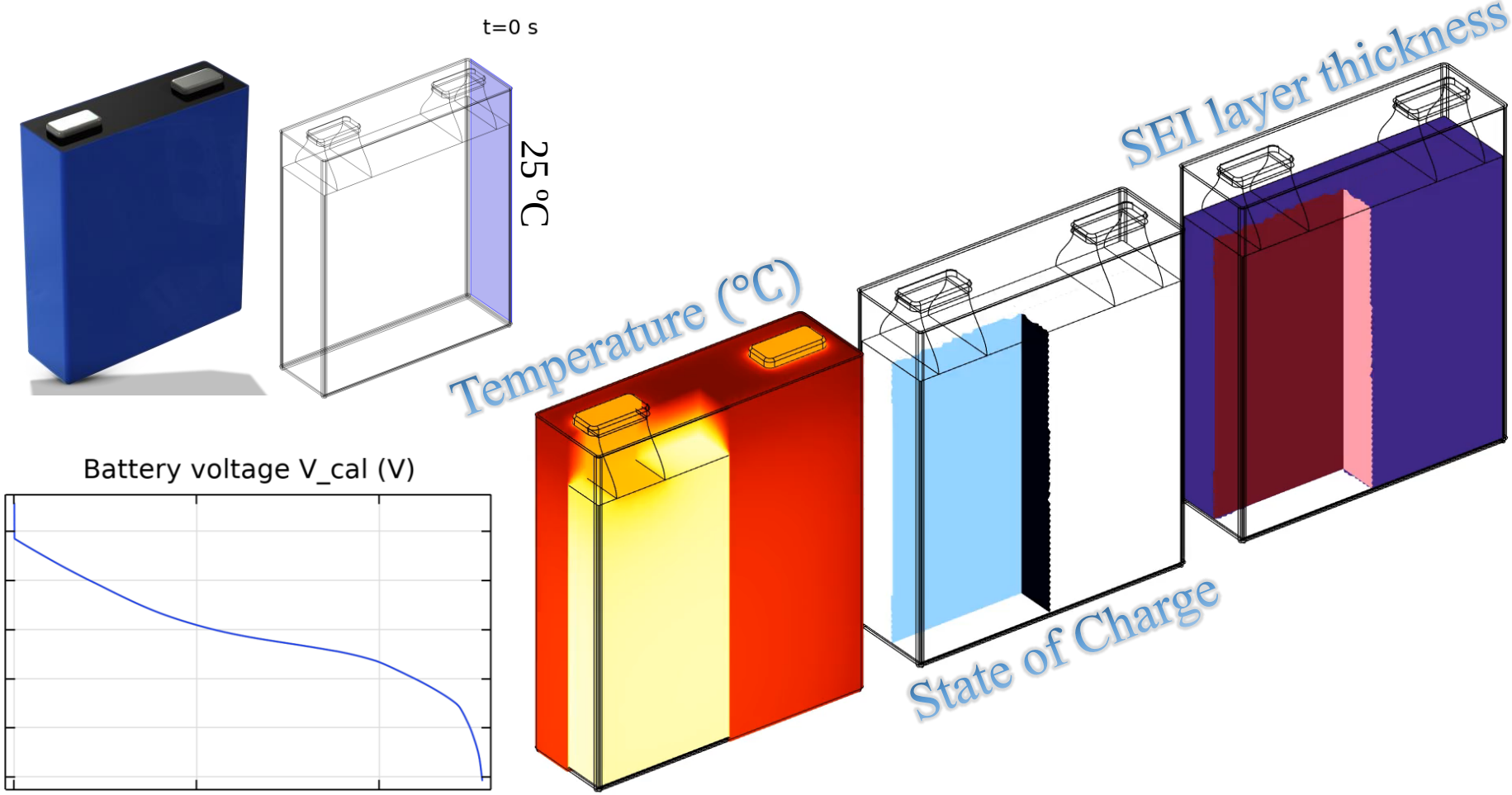
$$Ave\left(\left|\frac{V_{SEI} - DNN_{V_{SEI}}}{V_{SEI}}\right|\right) = 0.32\%$$

$$Ave\left(\left|\frac{dH - DNN_{dH}}{dH}\right|\right) = 2.4\%$$

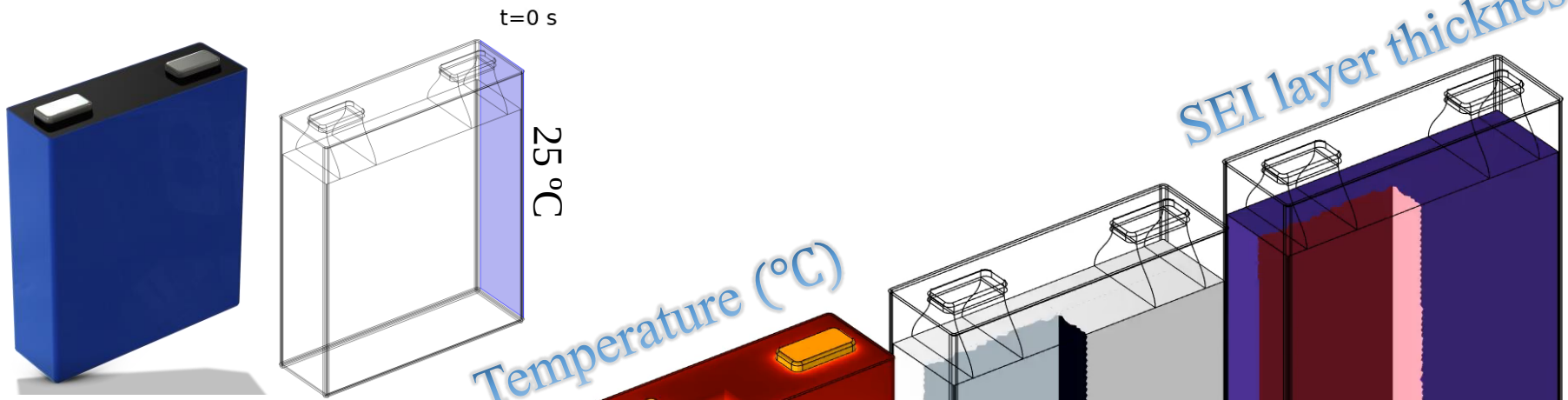
Deploying Deep Neural Networks in COMSOL Reduced Order Models

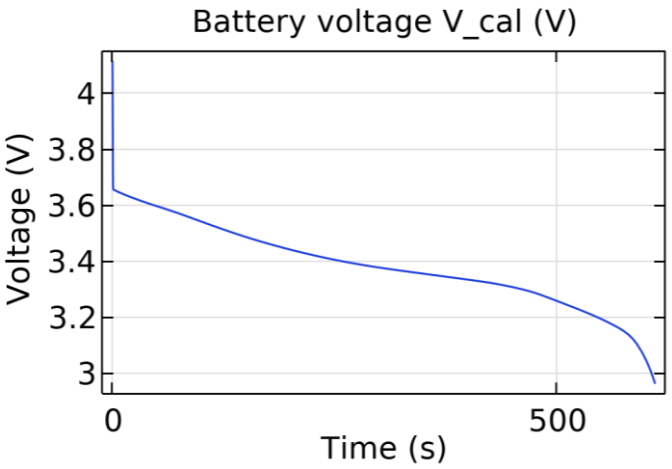


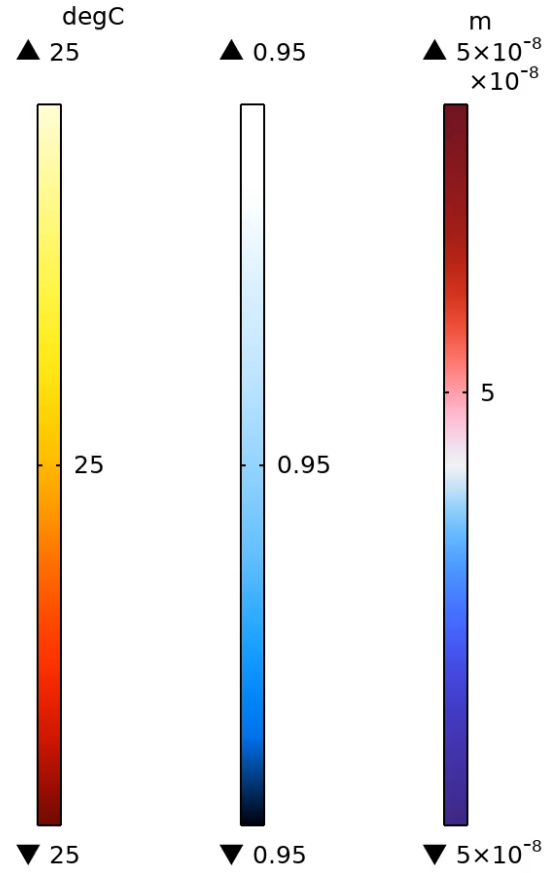
Degradation – Full Battery Cell 300A Discharge



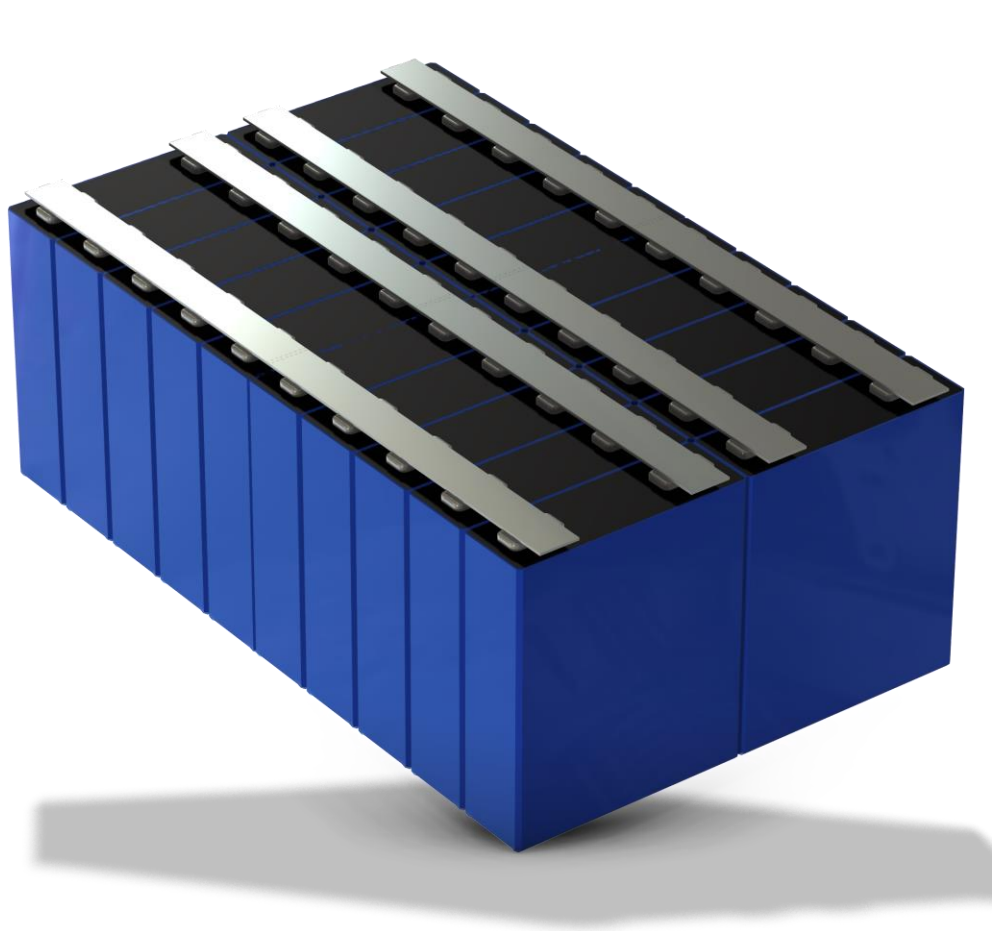
Degradation – Full Battery Cell 1200A Discharge

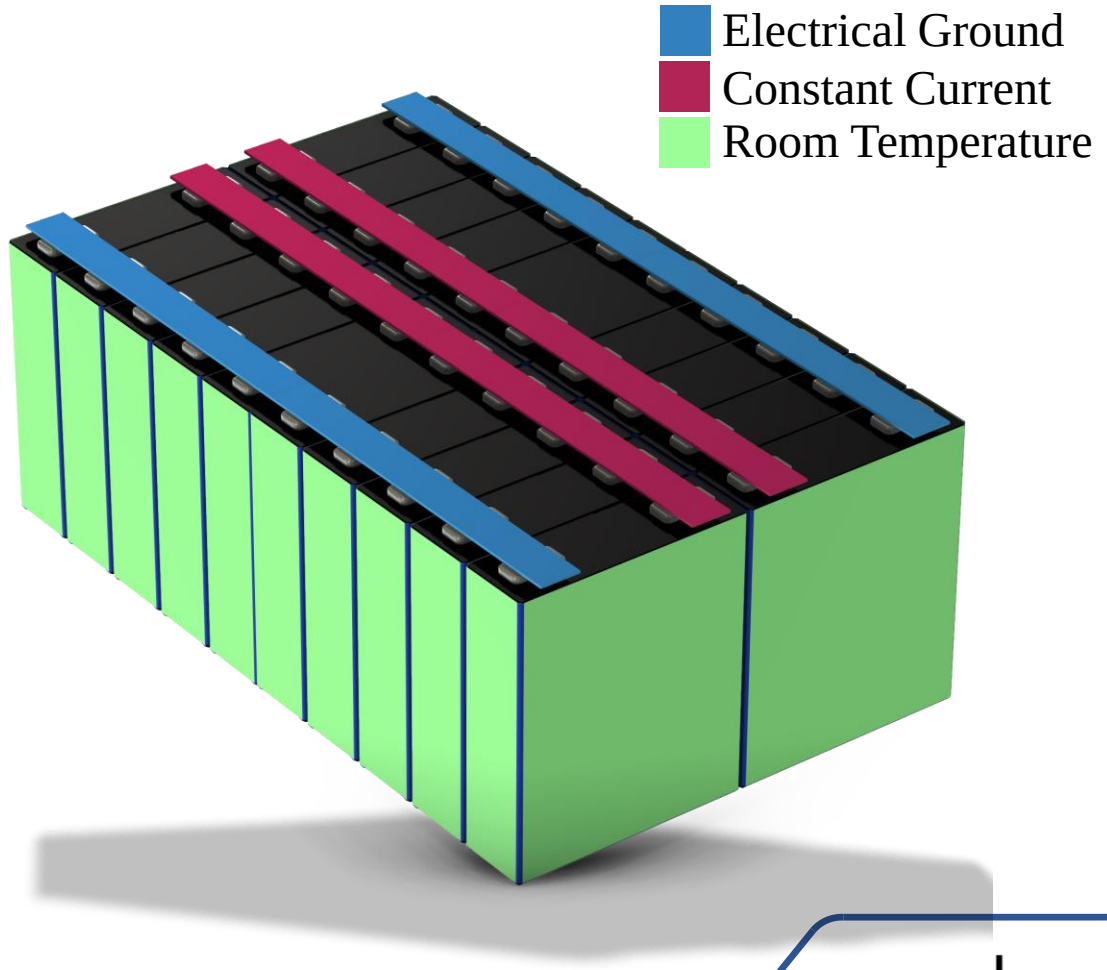




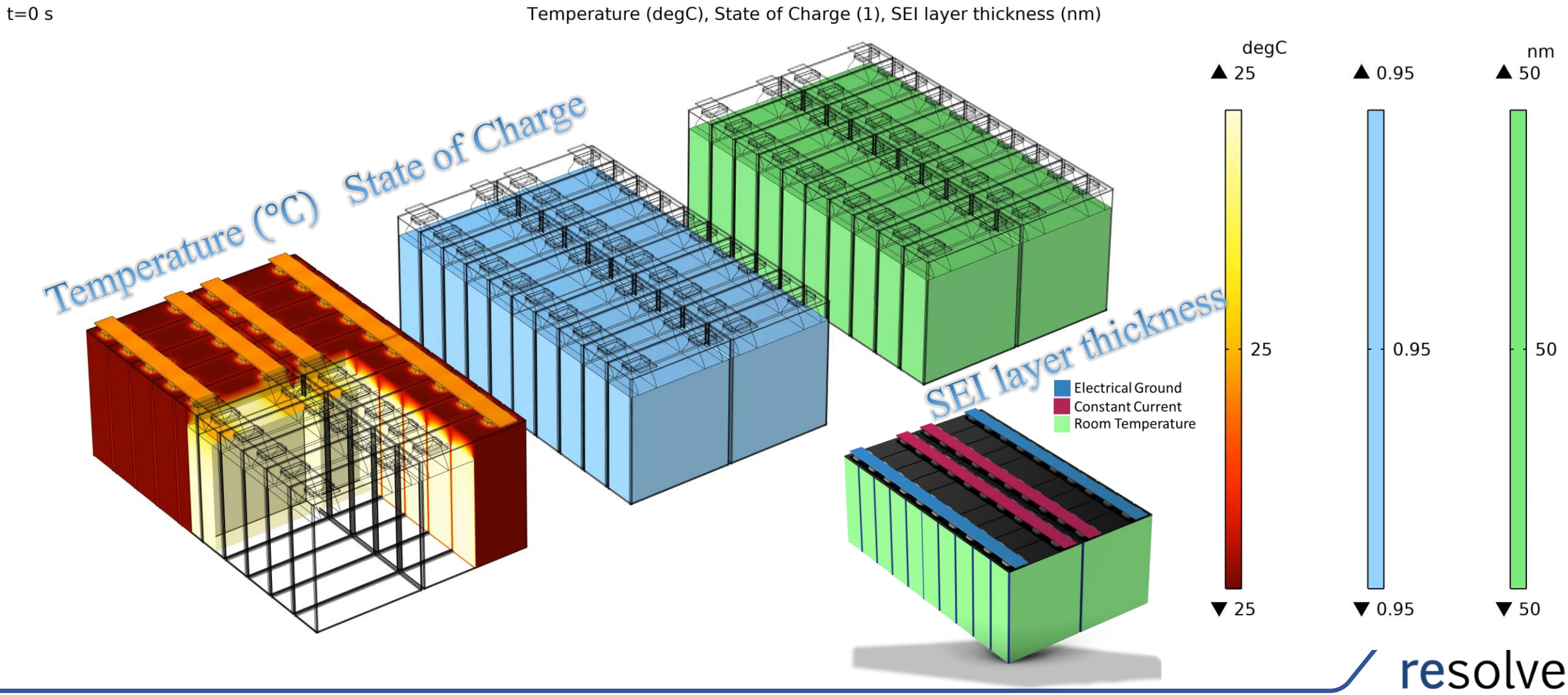


Going from Cell to Module degradation

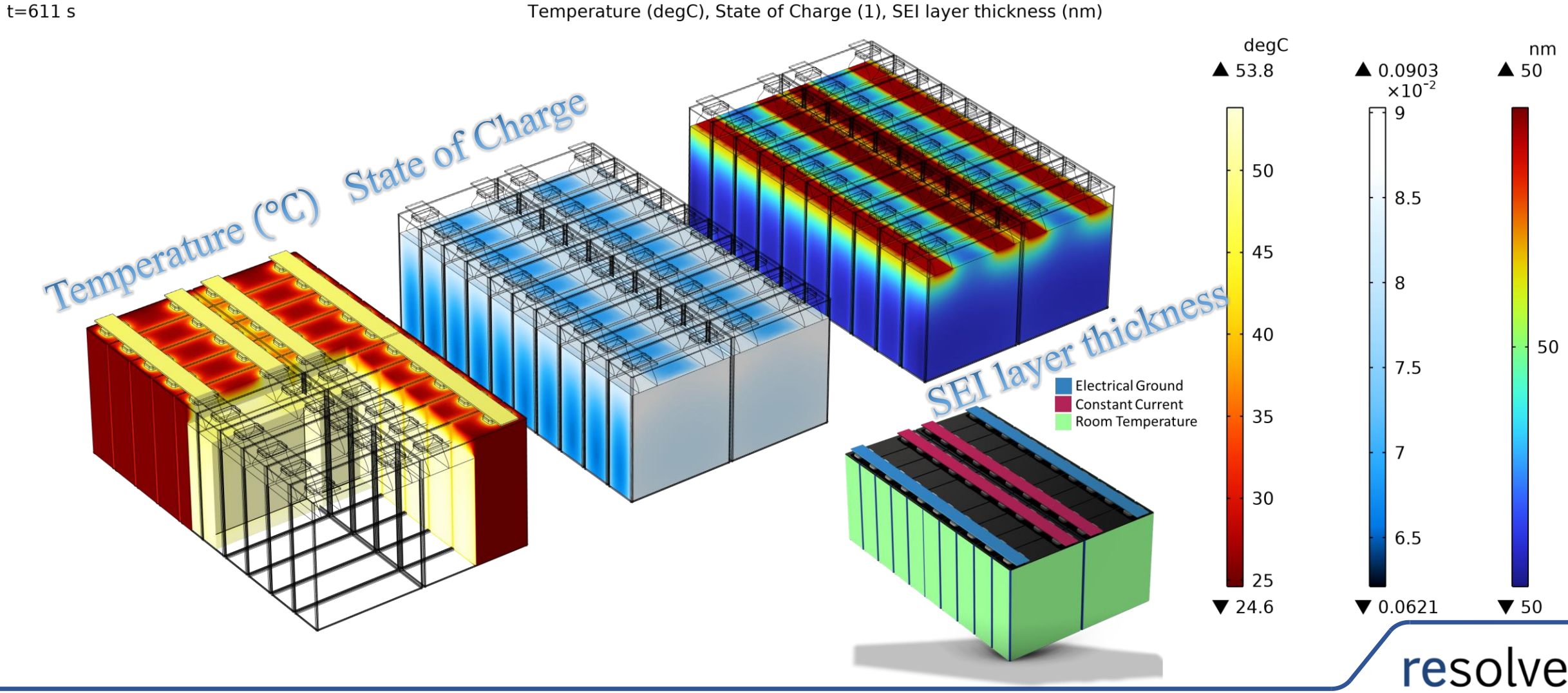




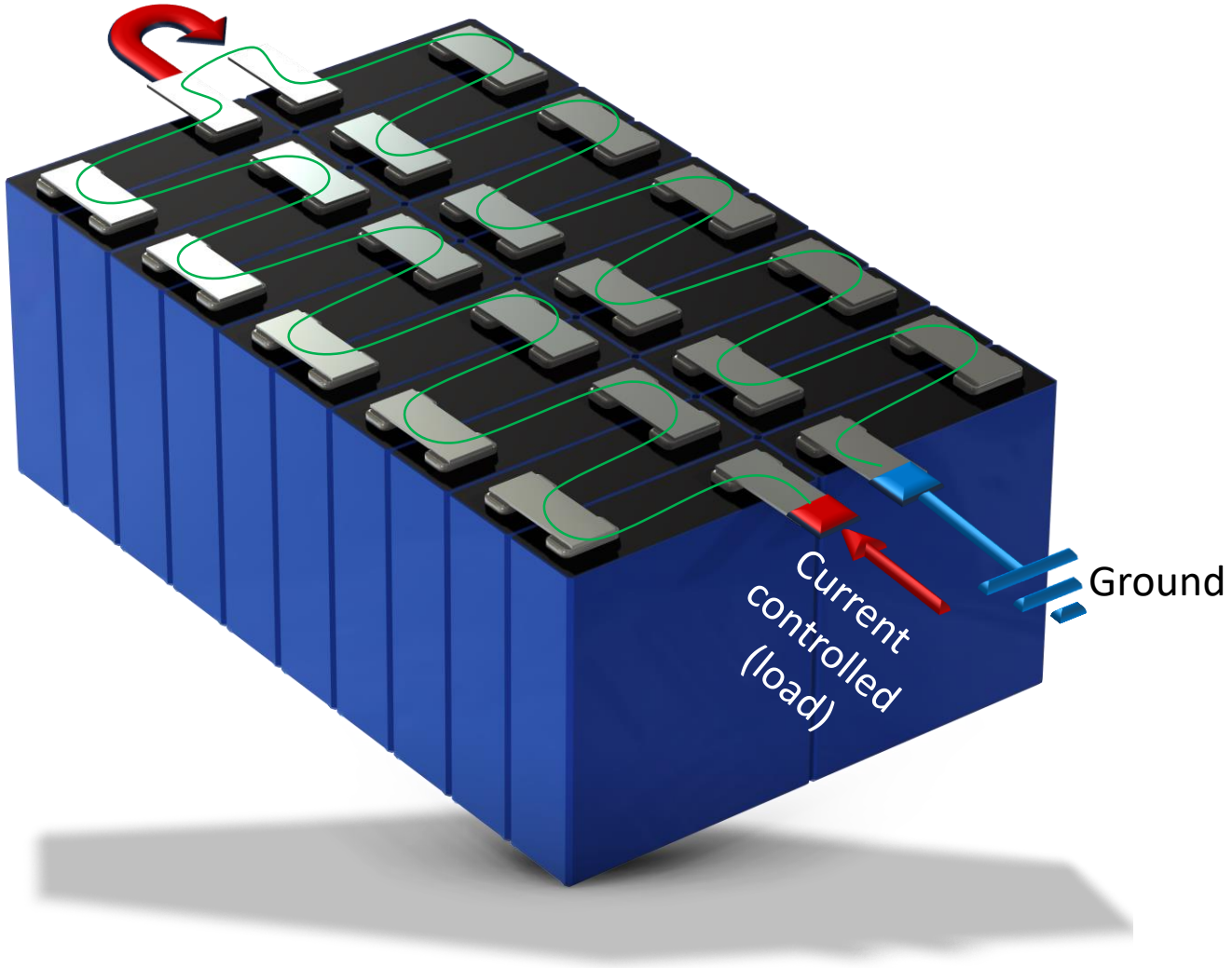
Going from Cell to Module degradation



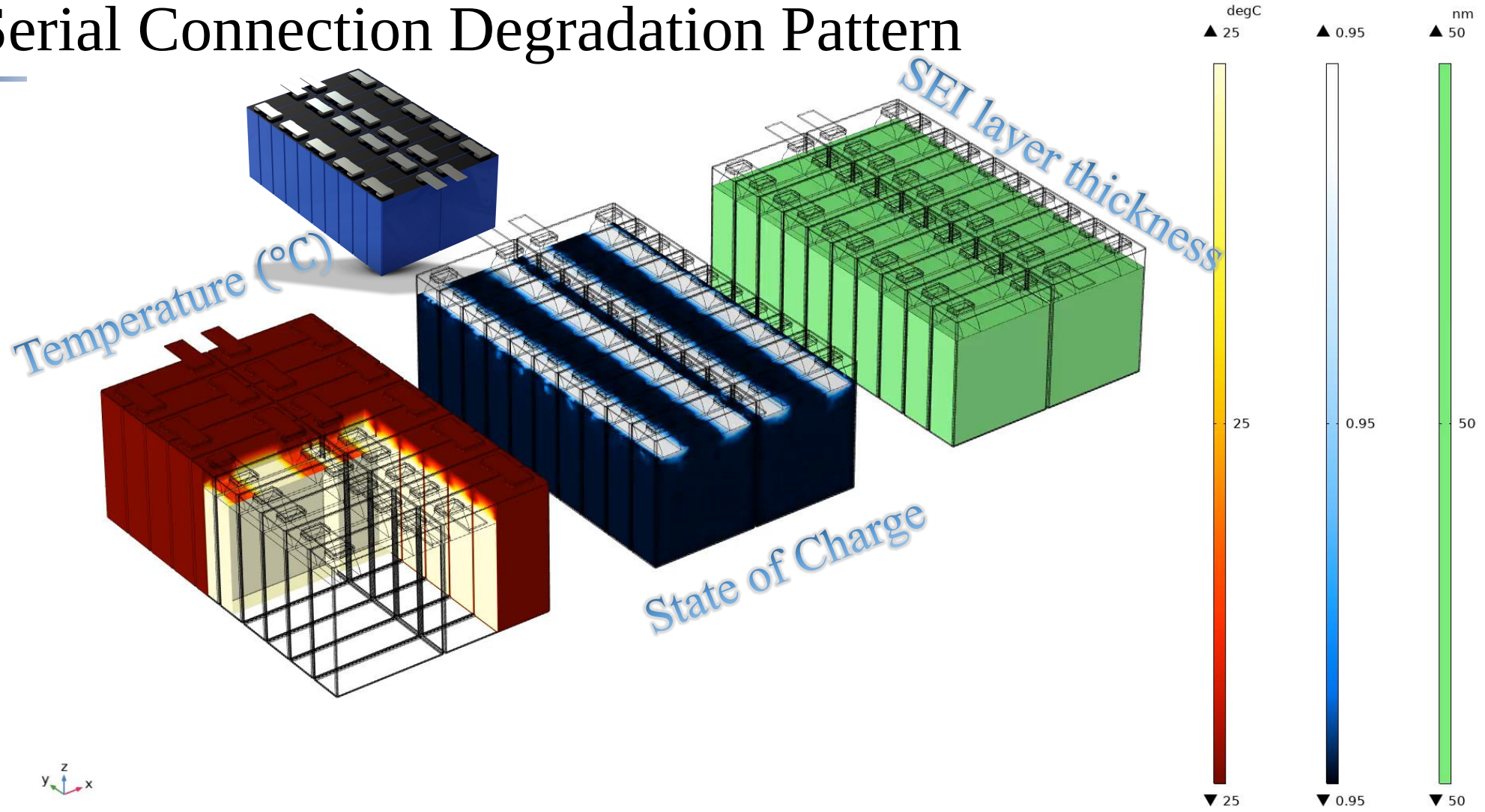
Going from Cell to Module degradation



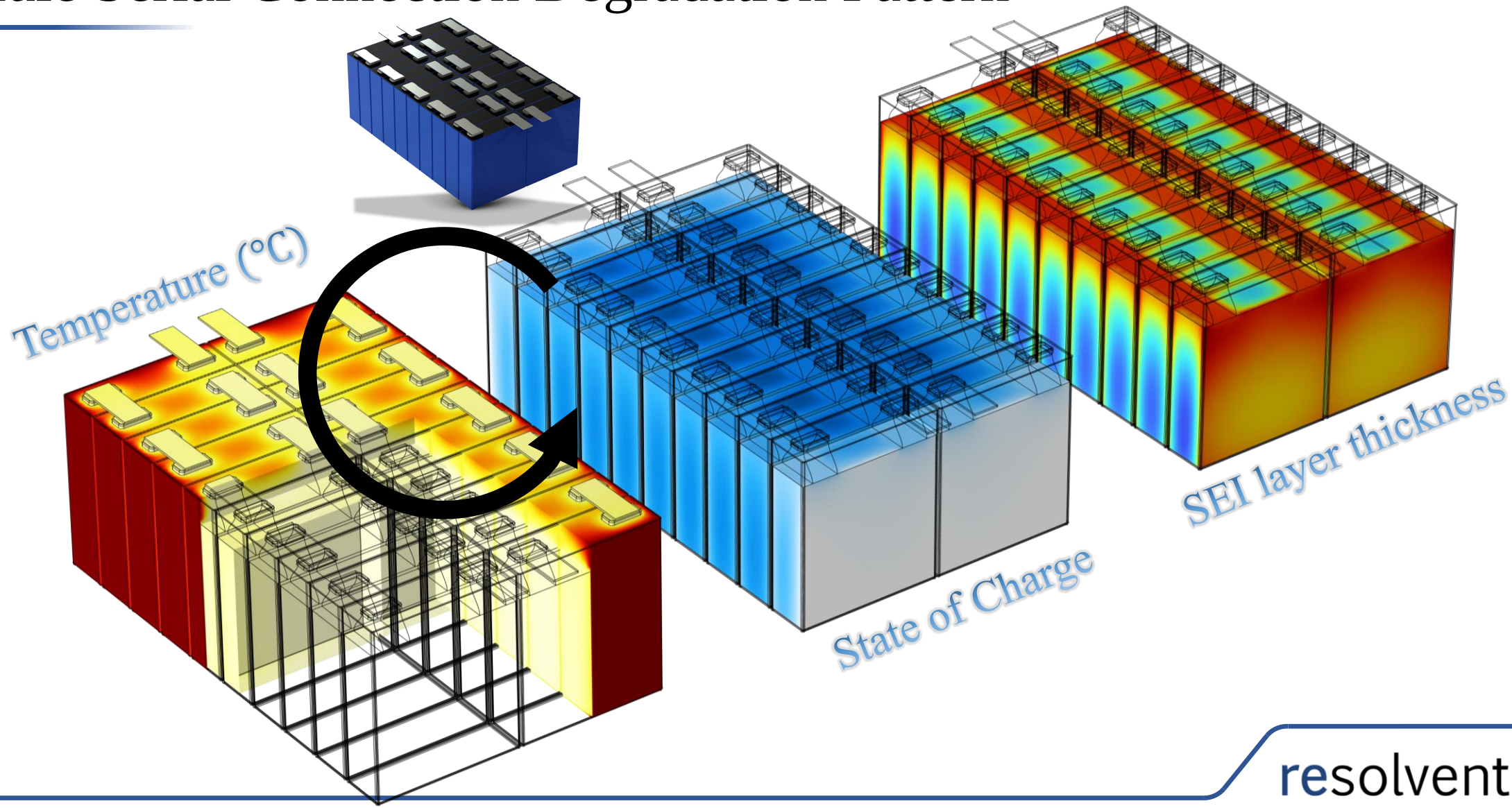
Module Serial Connection for High voltage



Module Serial Connection Degradation Pattern

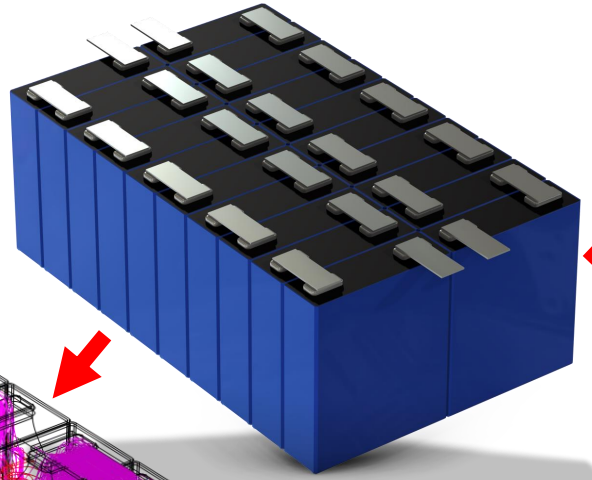


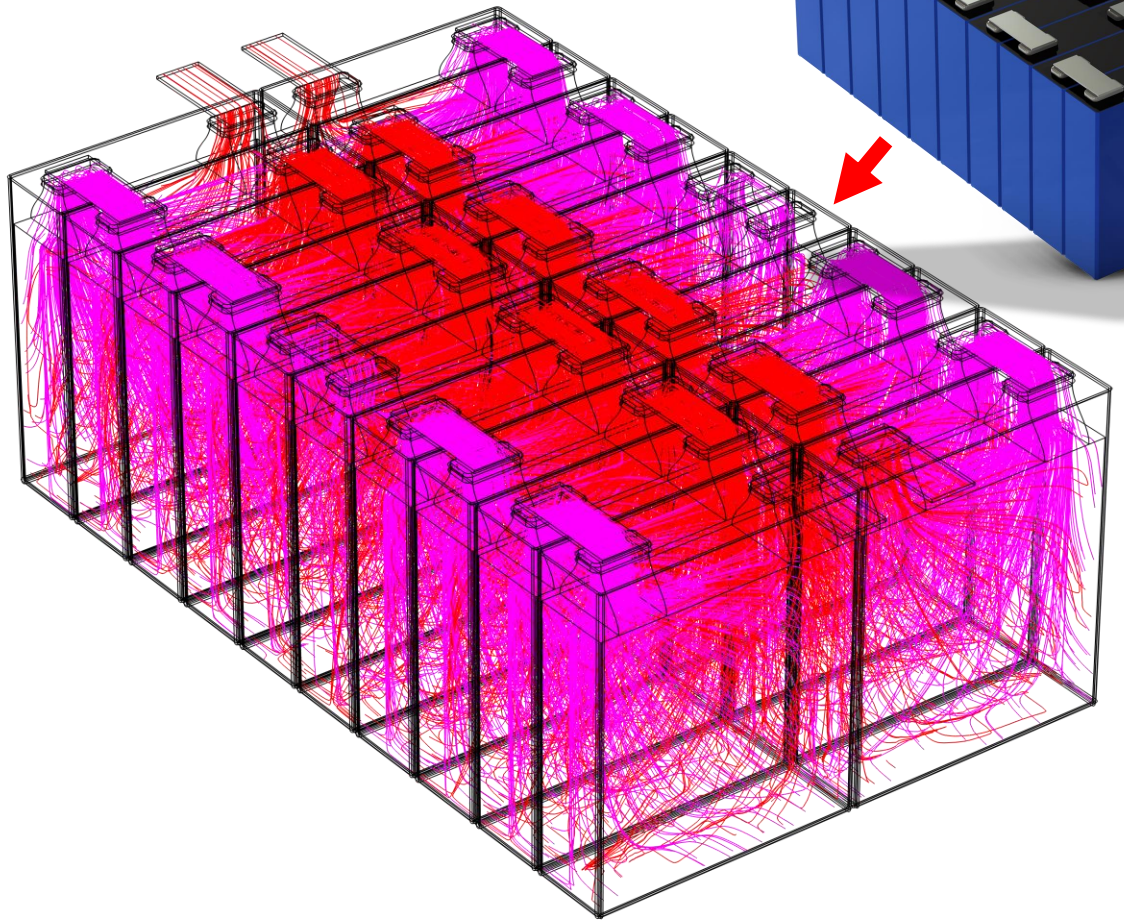
Module Serial Connection Degradation Pattern



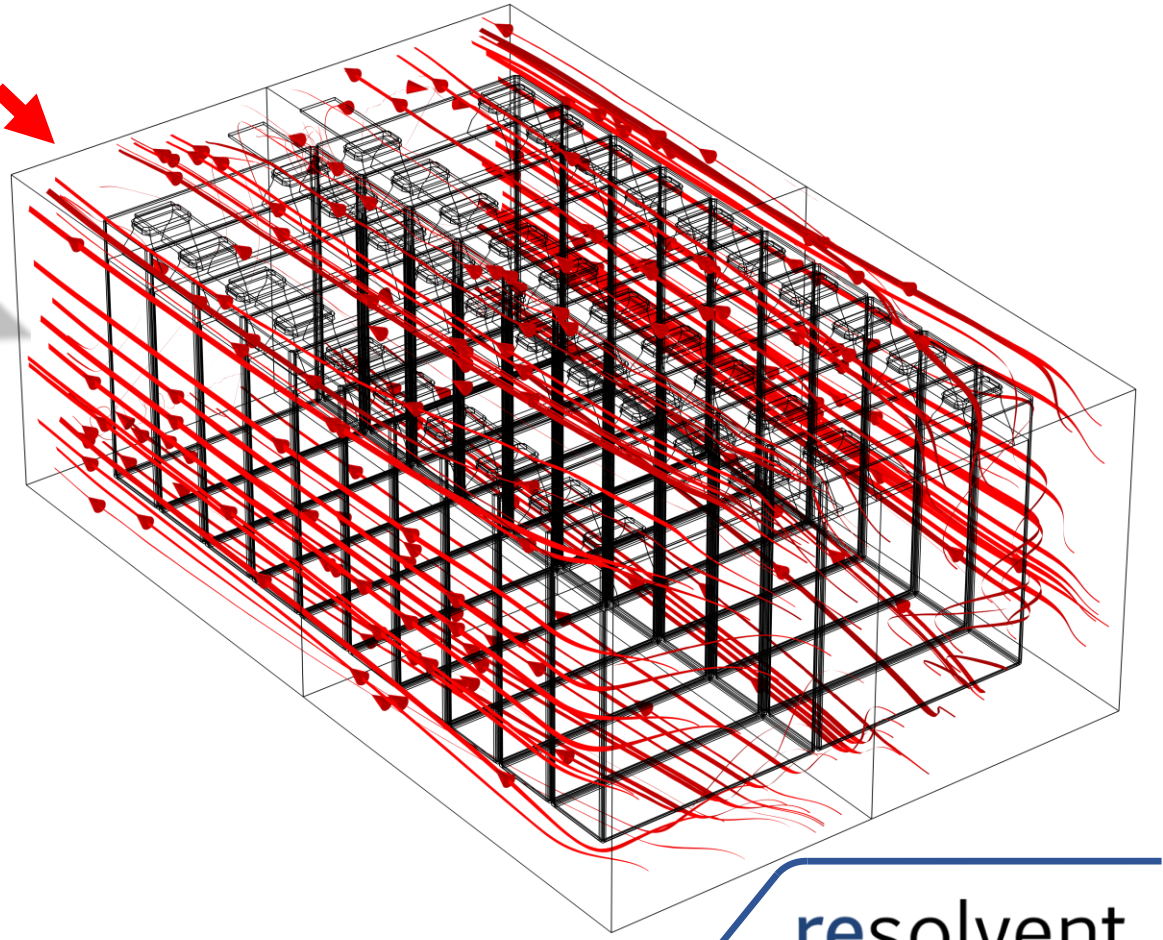
Module including physics important for temperature of module

Current distribution

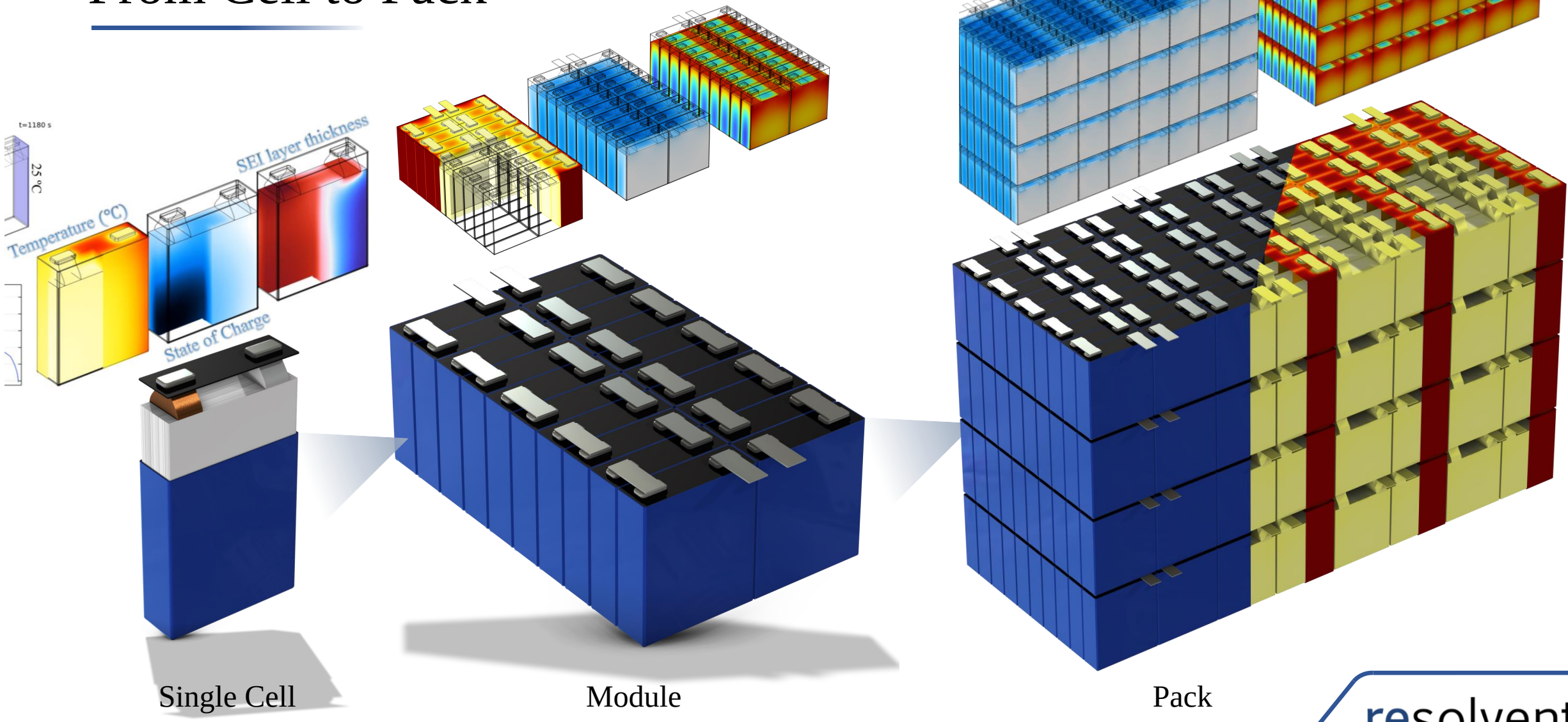




Flow distribution for cooling



From Cell to Pack



Single Cell

Module

Pack

Thank you for listening

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Thomas Bisgaard
Email: tb@resolvent.dk

Martin Refslund Nielsen
Email: mrn@resolvent.dk

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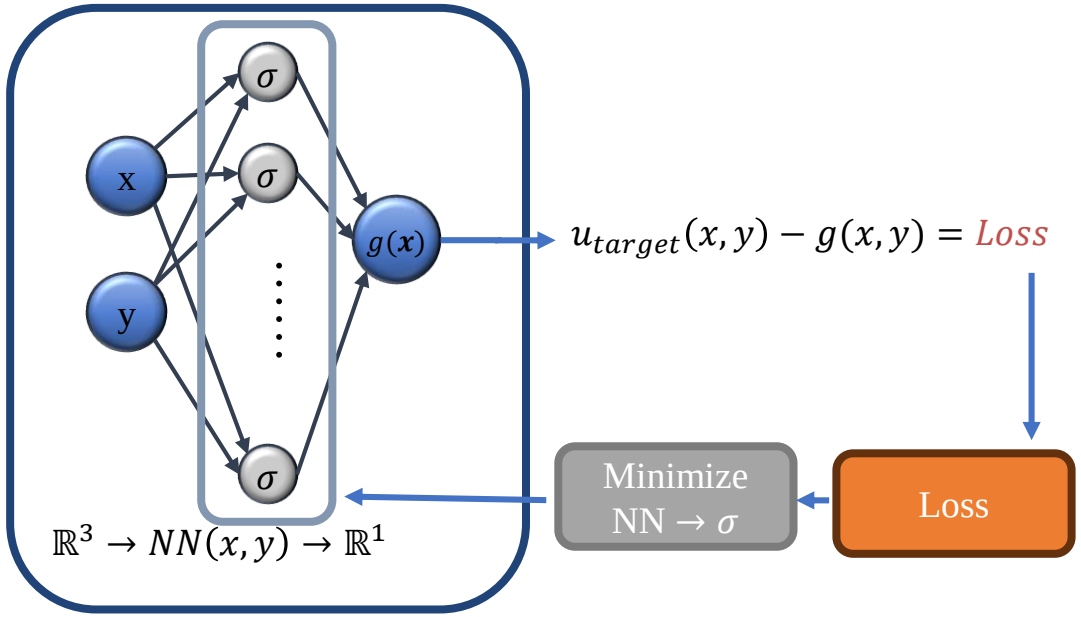
The authors would like to acknowledge the financial support by the European M-ERA.NET 3 call (project9468 LaserBATMAN), Innovation Fund Denmark (grant number 1139-00001), and the Swedish Governmental Agency for Innovation Systems (Vinnova grant number 2022-01257).

End of presentation

What is COMSOL surrogate modelling

Type	Settings
Dense	Input, Input features=4, Output features=50, Activation=tanh
Dense	Hidden, Output features=40, Activation=tanh
Dense	Hidden, Output features=30, Activation=ReLU
Dense	Hidden, Output features=20, Activation=ReLU
Dense	Output, Output features=1, Activation=Linear (none)



Preprocessing in model builder

DOE sampling methods, like Latin hypercube sampling (LHS)

On some parameter space

Parameter	Source type	Parameter description
r0 (Radial position)	Analyt	Uniform from [0, 0.1]
z0 (Axial position)	Analyt	Uniform from [0, 1]
E (Activation energy)	Analyt	Uniform from [71518, 79205]
ke (Thermal conductivity)	Analyt	Uniform from [0.0559, 5.6]
dHrx (Heat of reaction)	Analyt	Uniform from [-101600, -67733]

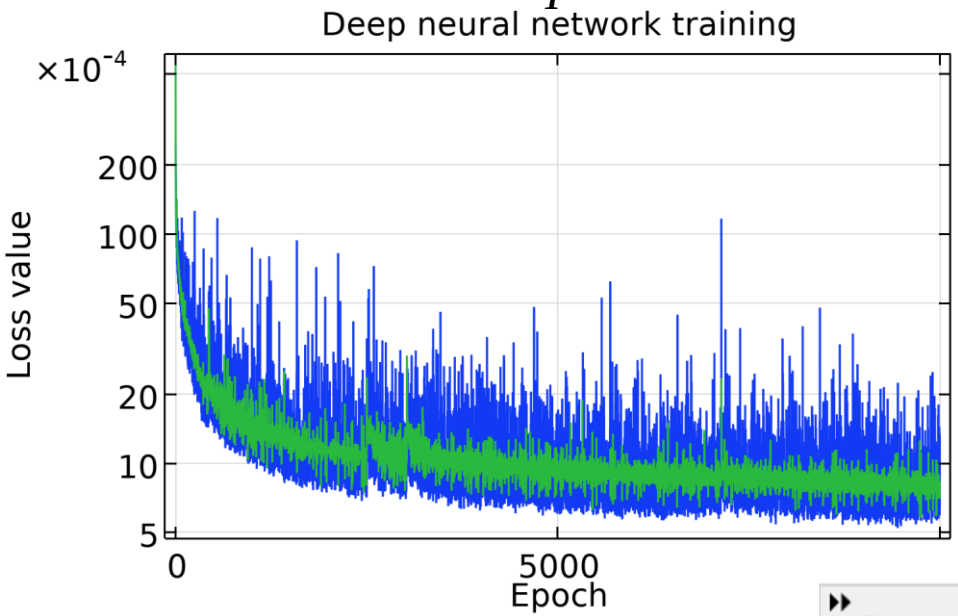
Generate table of all the values

Train Deep Neural Network (DNN) on the results table

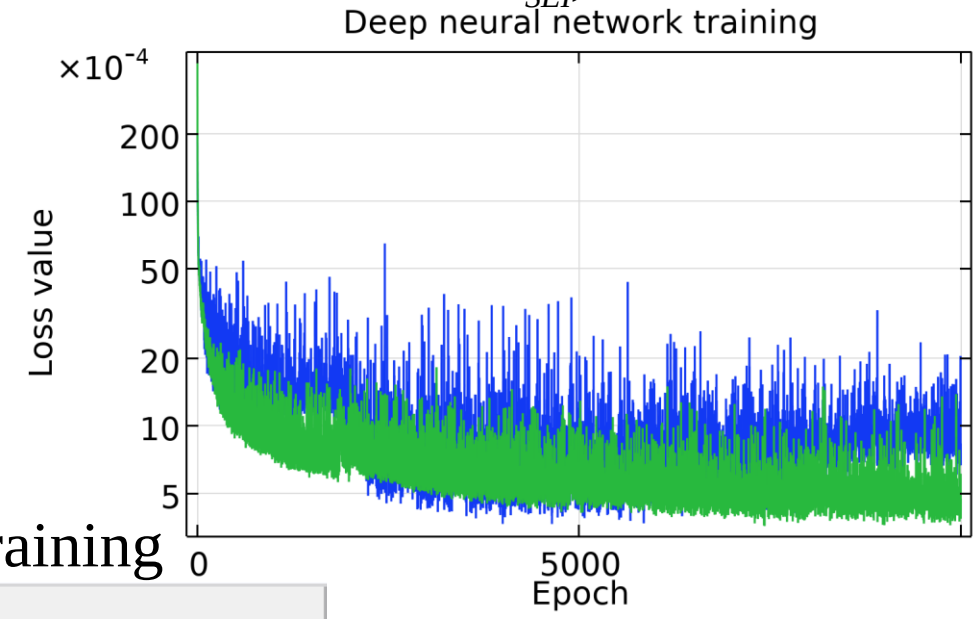
Use DNN in results to plot intermediate solutions for some coordinates r, z and the parameter E, ke, dHrx

Learnings from surrogate modelling

I



V_{SEI}, dH



Example of DNN training

Type	Settings
Dense	Input, Input features=4, Output features=50, Activation=tanh
Dense	Hidden, Output features=40, Activation=tanh
Dense	Hidden, Output features=30, Activation=ReLU
Dense	Hidden, Output features=20, Activation=ReLU
Dense	Output, Output features=1, Activation=Linear (none)

$$Ave\left(\left|\frac{I - DNN_I}{I}\right|\right) = 0.18\%$$

$$Ave\left(\left|\frac{V_{SEI} - DNN_{V_{SEI}}}{V_{SEI}}\right|\right) = 0.32\%$$

$$Ave\left(\left|\frac{dH - DNN_{dH}}{dH}\right|\right) = 2.4\%$$