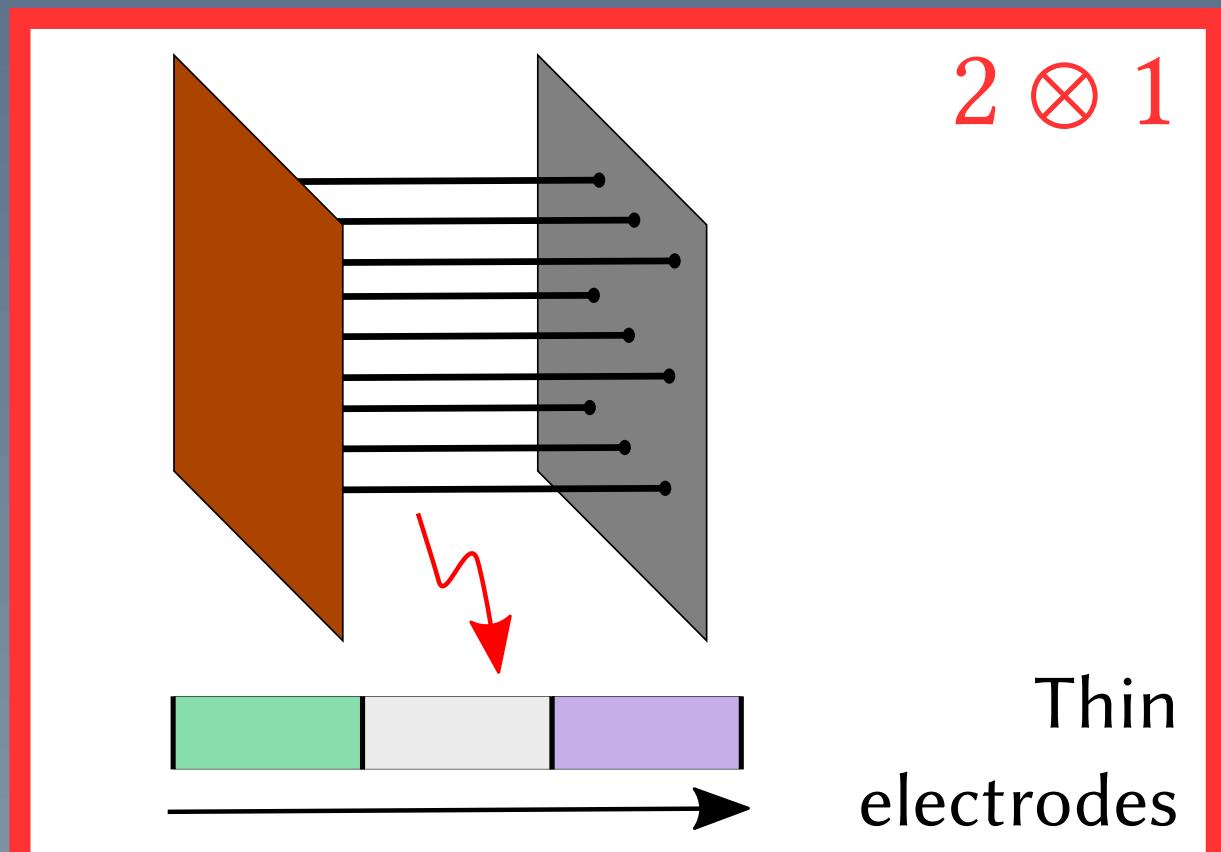
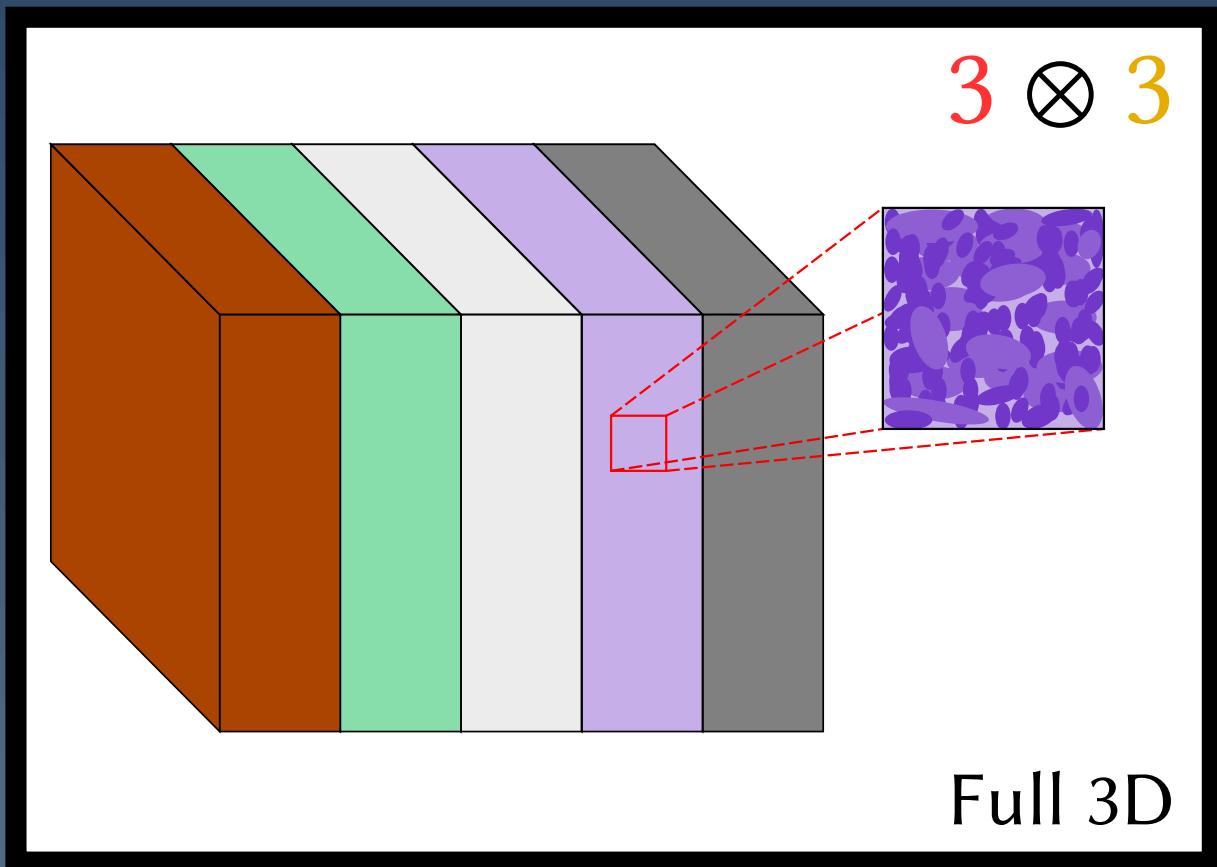


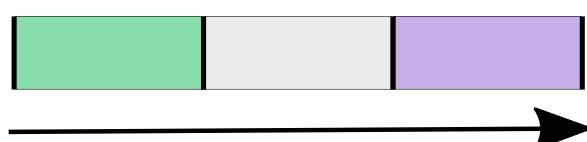
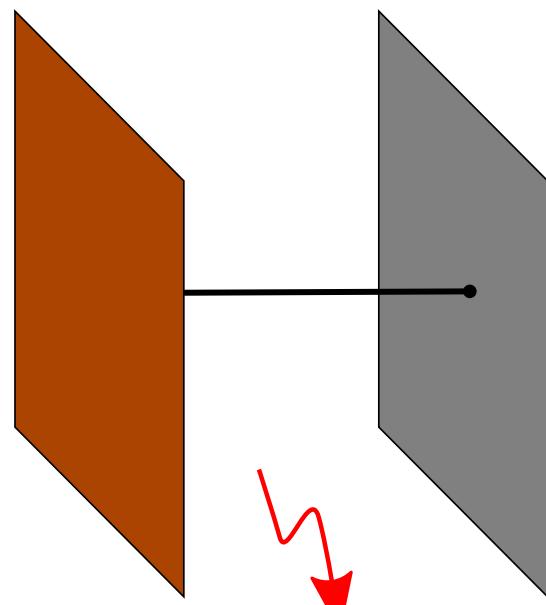


---

Electrochemical and equivalently expensive and the physics-based models, which design. Combinations of simplicity and fidelity can be selected order models which is indeed side reactions and degradation.

models numerically.



$2 \otimes \bar{1}$ 

Large conductivity

 $0 \otimes 1$ 

Very large conductivity

$0 \otimes 0$



Fast diffusion  
in electrolyte

Diffusion

---

**EPSRC**

Engineering and Physical Sciences  
Research Council



# An Asymptotic for Battery

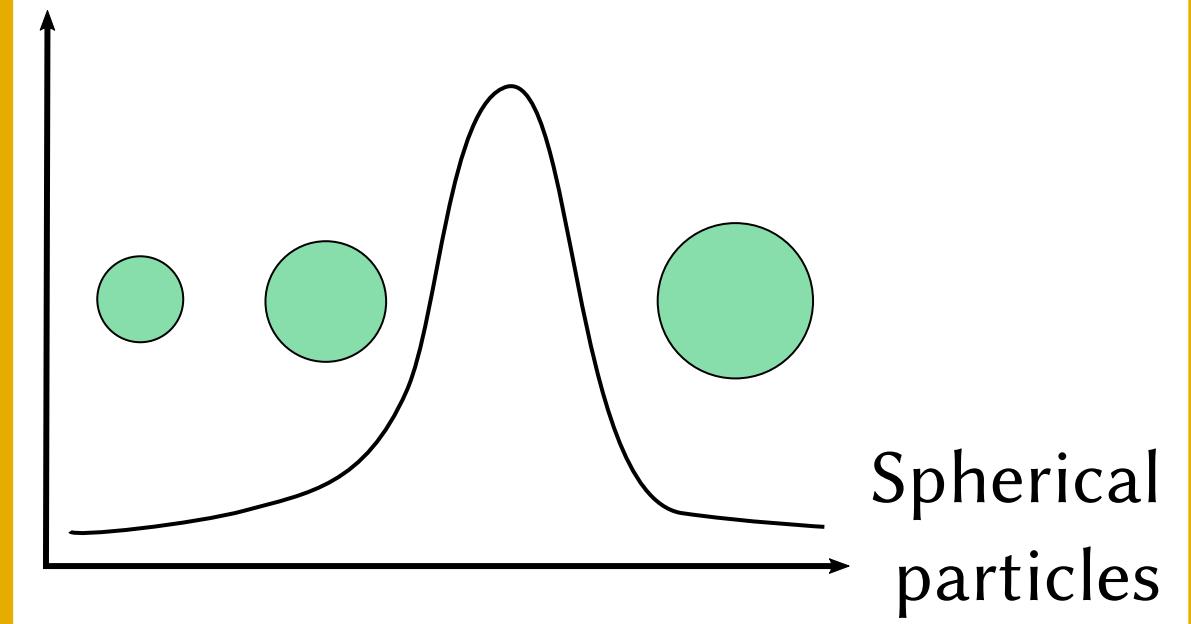
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Jon Chapman, Matt Hennessy,  
Colin Please, Ian Roper, Valeria

---

lent-circuit modelling are the two most common approaches to battery modelling. The latter provides limited physical insight, while the former does not. Both approaches provide a useful theoretical middle ground between the extremes. They can be applied to different length-scales, from simplifications to the **macroscale** and **microscale**, to best meet the user's needs. The approach is based on a detailed understanding of the underlying chemistry, and can be extended to incorporate various side-reactions and deactivation mechanisms. We are currently developing a new model for the

$1 \otimes 1$



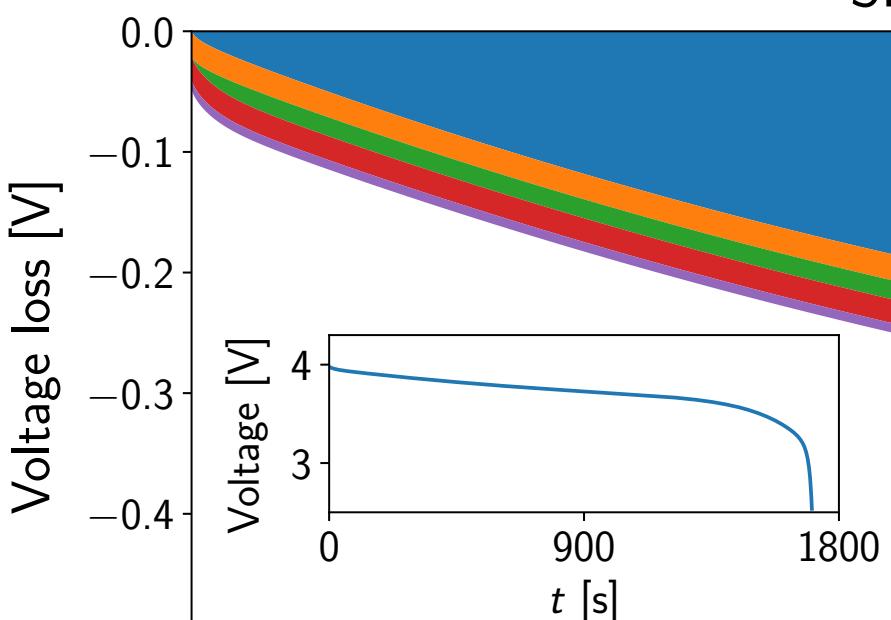
Complex



Complex

Lithium cobalt oxide

SPM

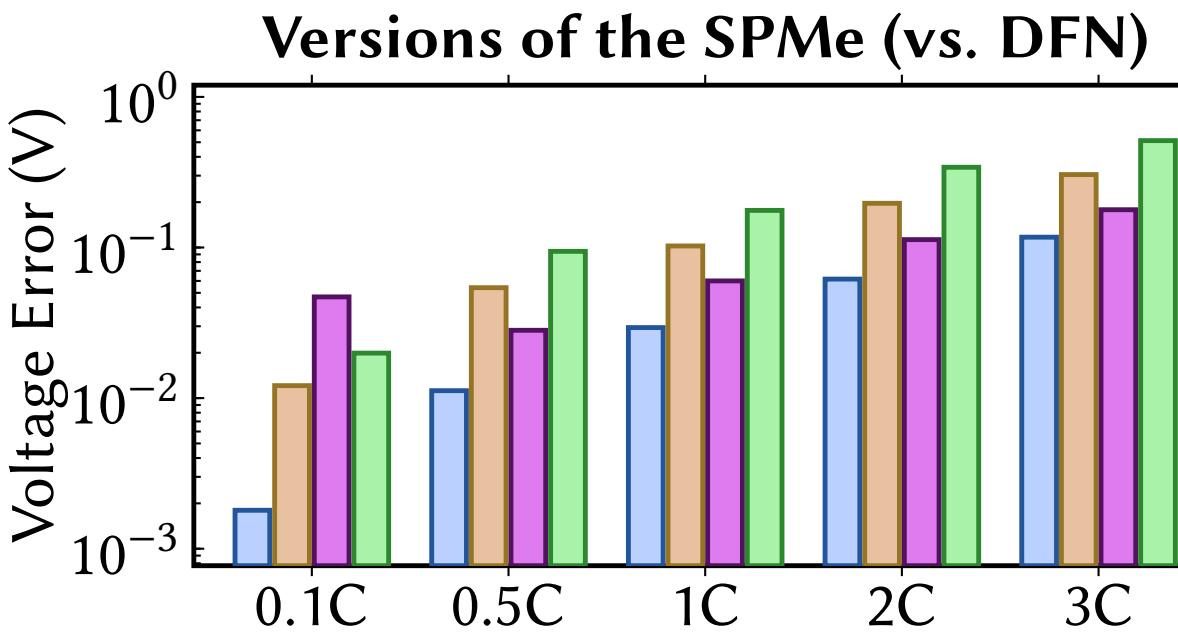
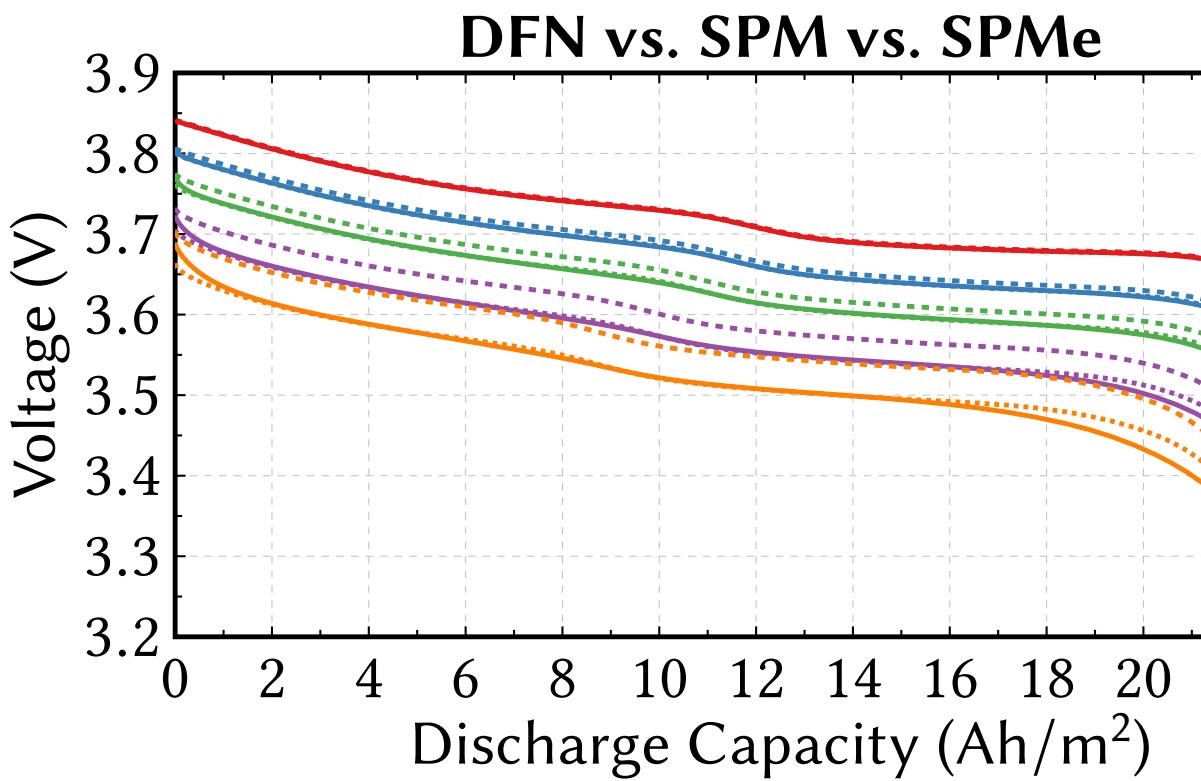


# MACROSCALE



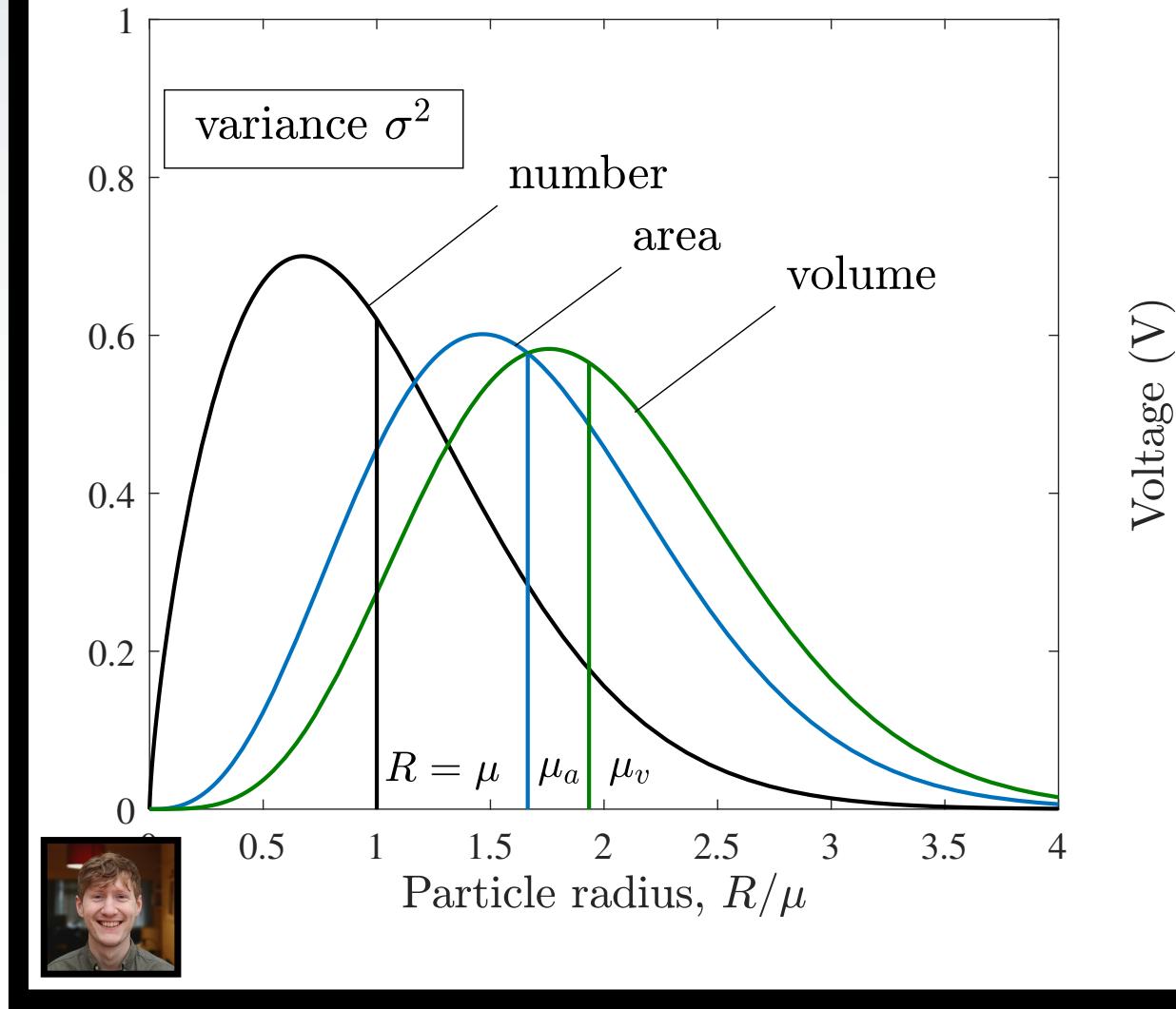
-0.5 0 450  
 $t [$

## Lithium cobalt oxide



# Lithium cobalt oxide

Simple



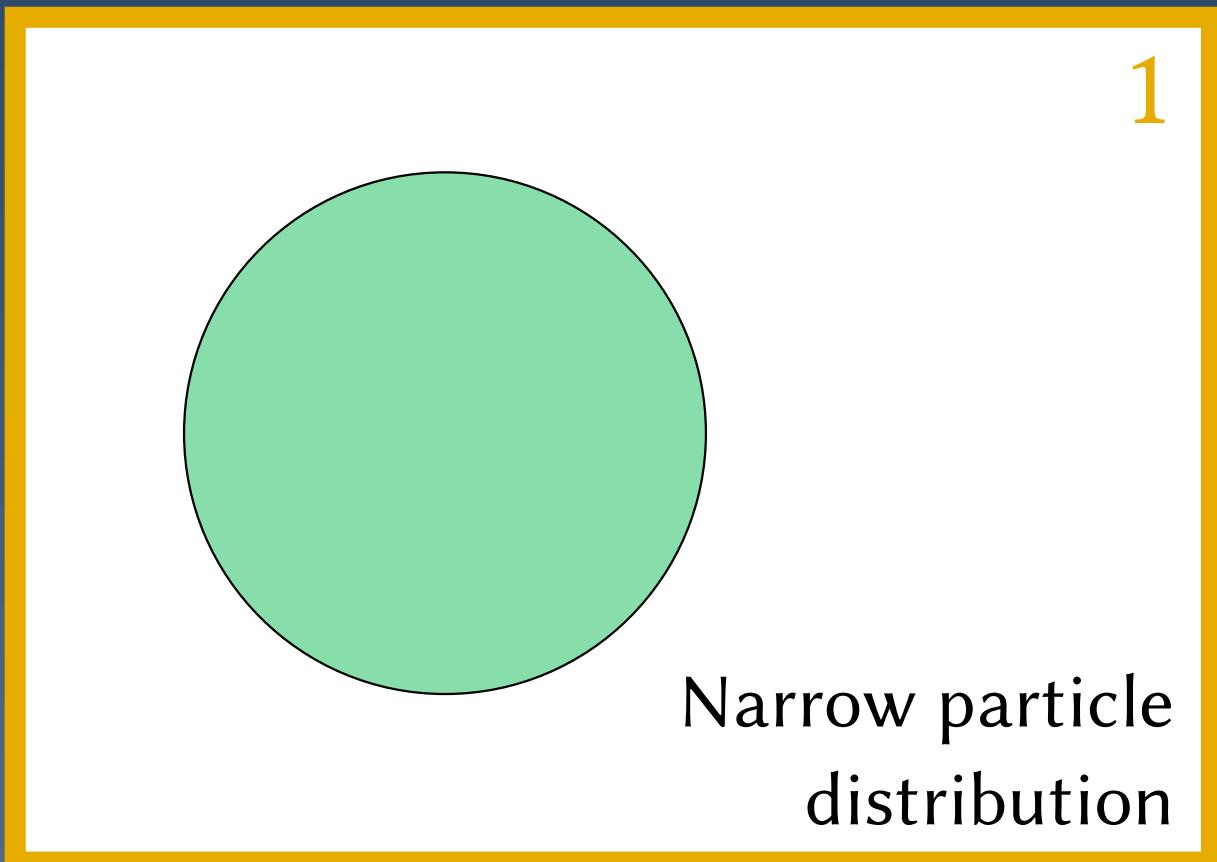
# ic Framework Modelling

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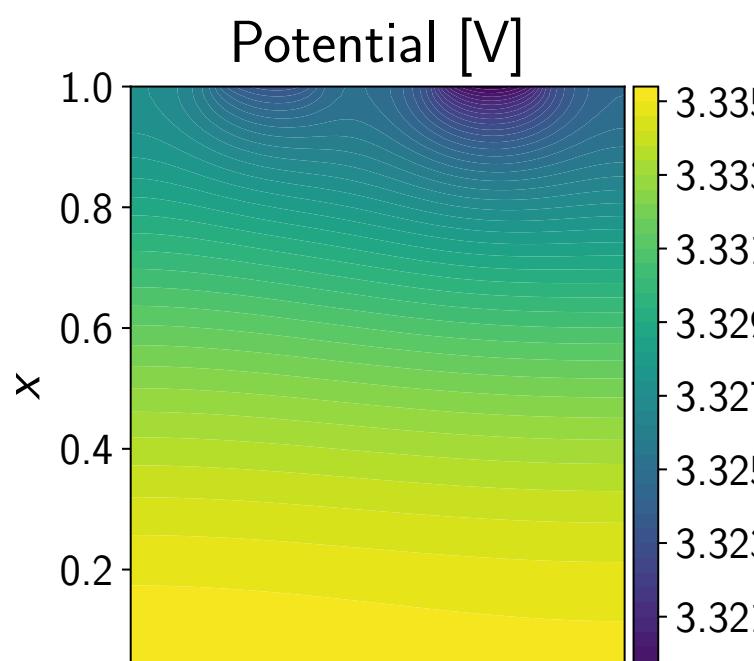
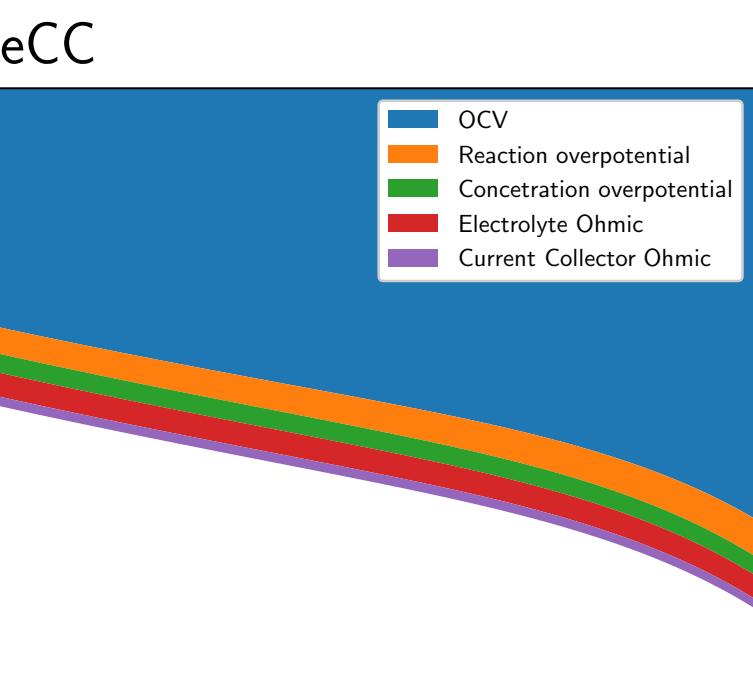
sy, Toby Kirk, Scott Marquis,  
entin Sulzer, Robert Timms.

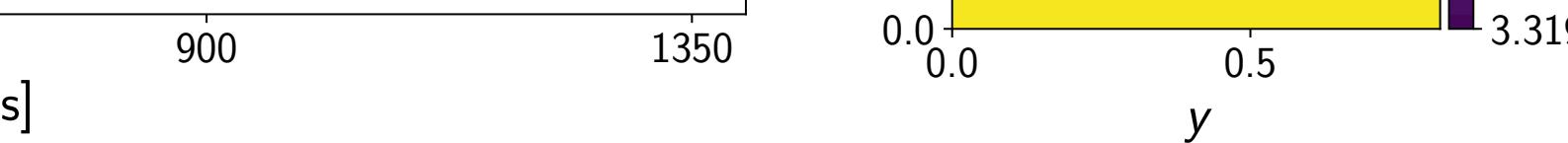
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popular approaches to battery simulation. Through asymptotic analysis, we systematically reduce the model to support battery management, enabling large-scale simulation. This multiscale result in a suite of reduced-order models. The approach taken provides a general framework for battery modelling, which can be extended to incorporate additional physical phenomena. We demonstrate this by developing the software package PyBaMM, which provides a high-level interface for battery simulation.

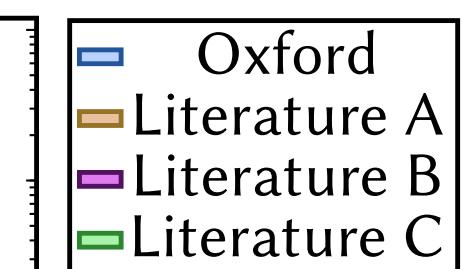
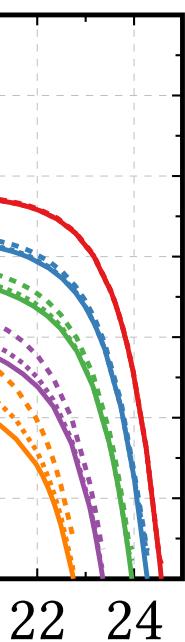


# MICROSCALE





s]

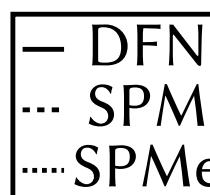
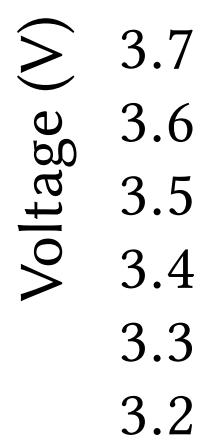


SPMeCC

DFN

SPMe

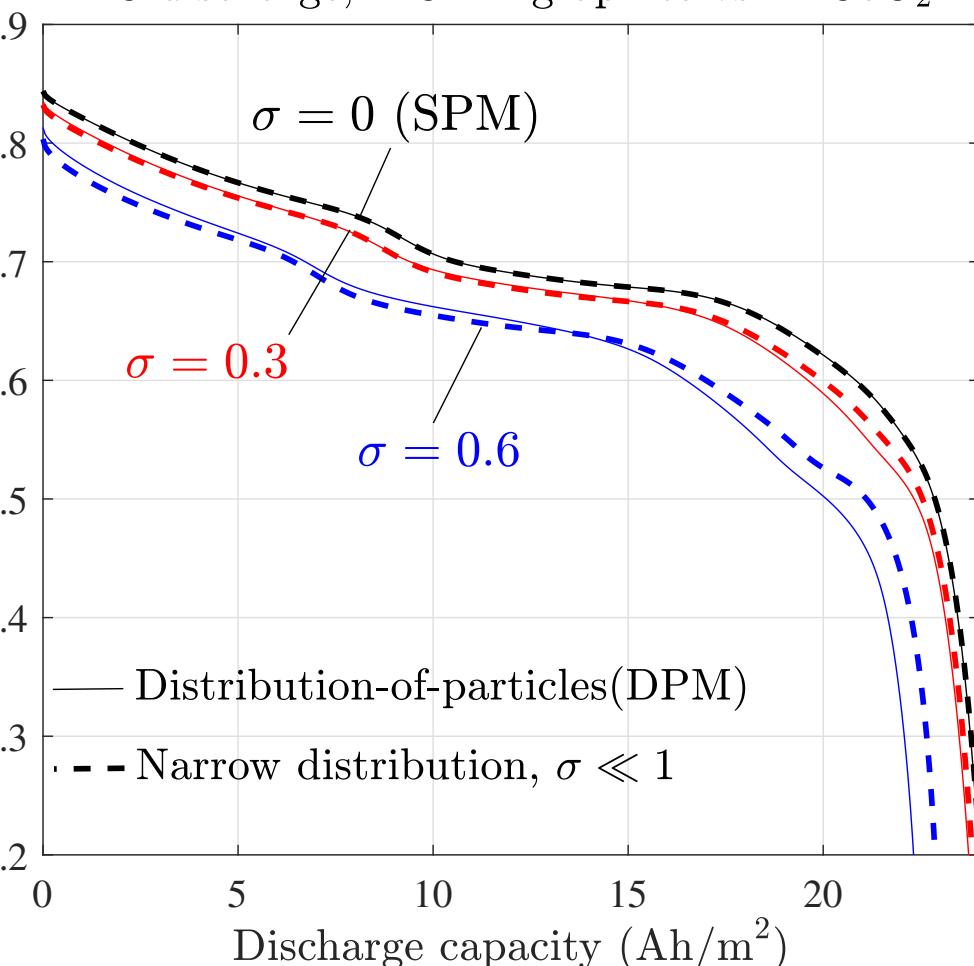
Lead-a



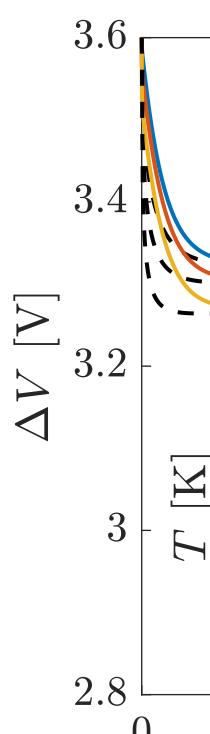
MPM

SPM

1C discharge, MCMB graphite vs. LiCoO<sub>2</sub>

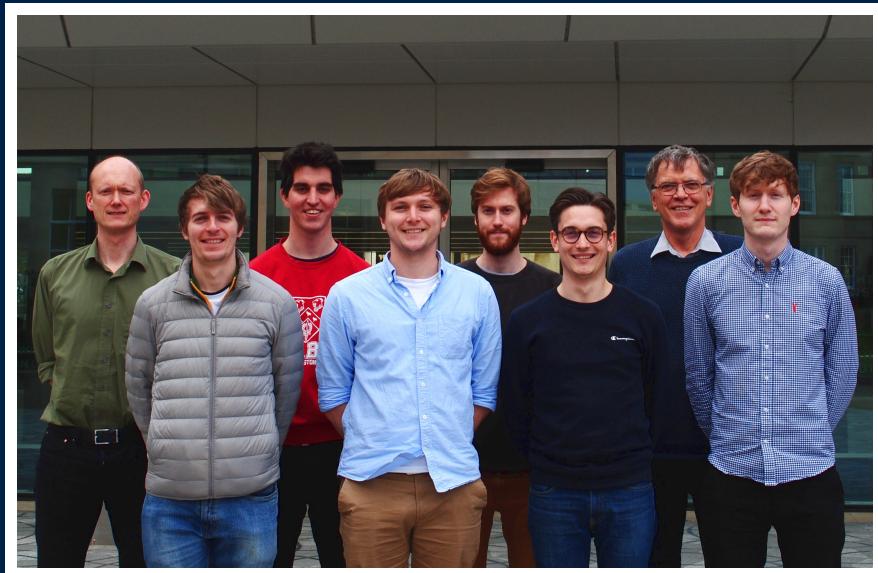


Lithium



SIEMENS

nexeo



on, but the former is computationally derive simplified on-line diagnostics, and cell models, whose complexity work for developing reduced-effects such as mechanics, & to implement the suite of

0



Fast diffusion  
in particles

Simple



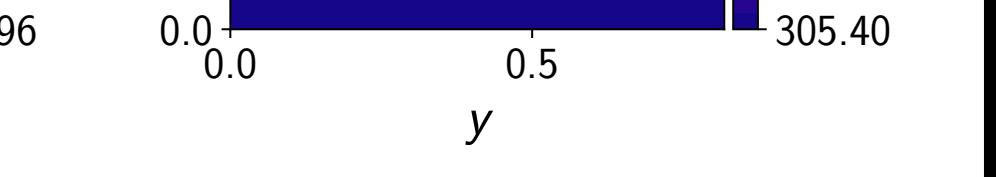
Temperature [K]

56  
36  
16  
96  
76  
56  
36  
16

1.0  
0.8  
0.6  
0.4  
0.2

306.84  
306.68  
306.52  
306.36  
306.20  
306.04  
305.88  
305.72  
305.56

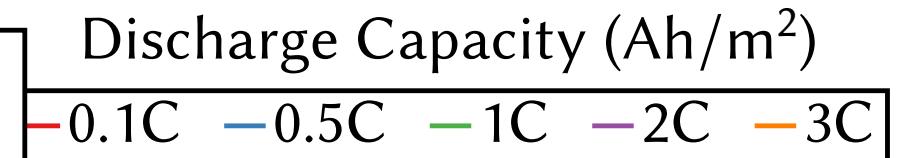
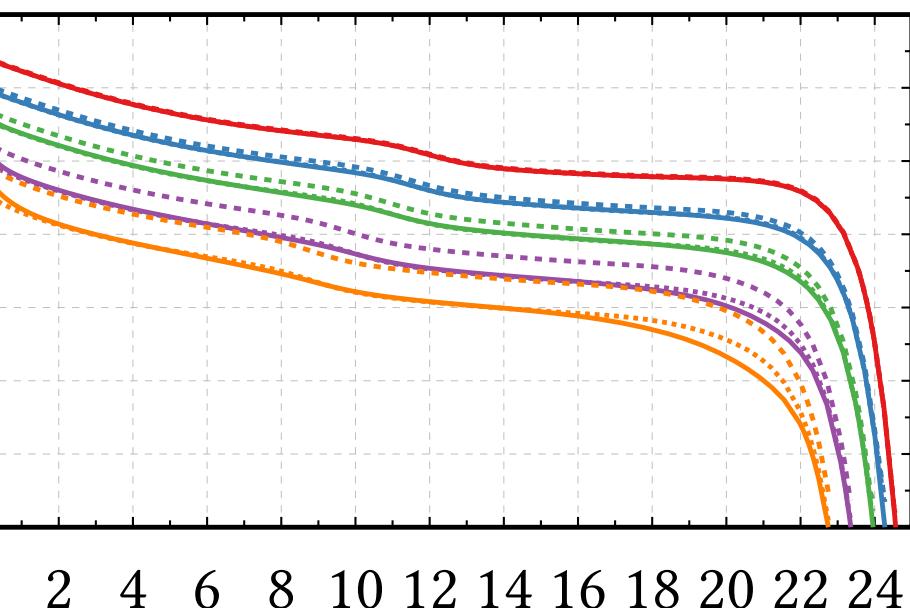
x

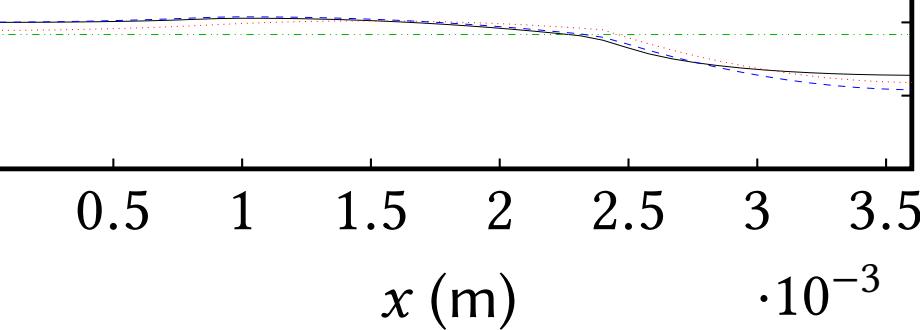


cid

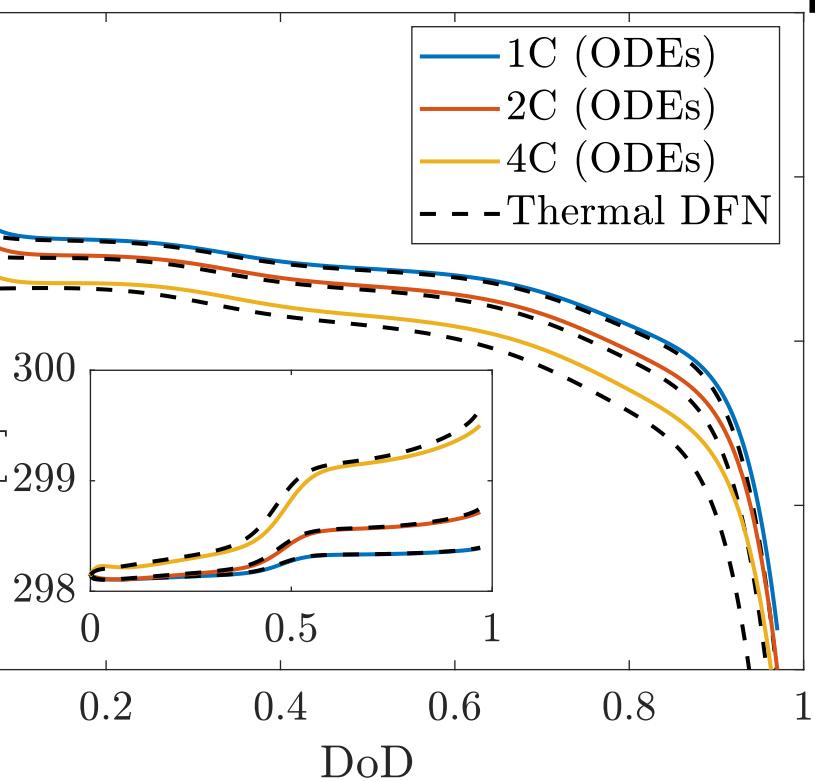


## DFN vs. SPM vs. SPMe





# in iron phosphate



n

