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# Accelerated rate calorimetry dedicated to the modelling of Li-ion batteries thermal runaway of fresh and aged cells

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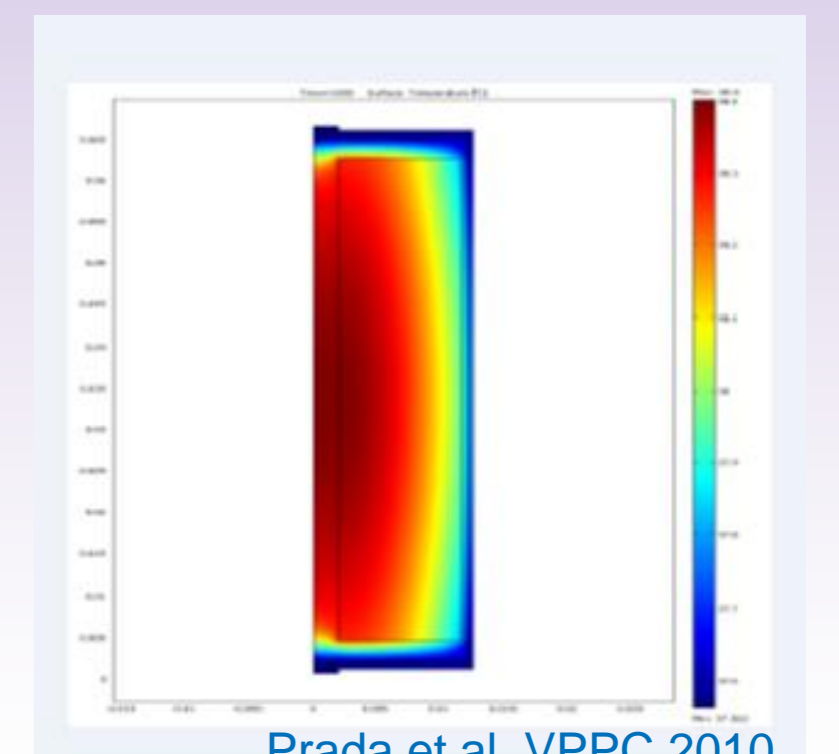
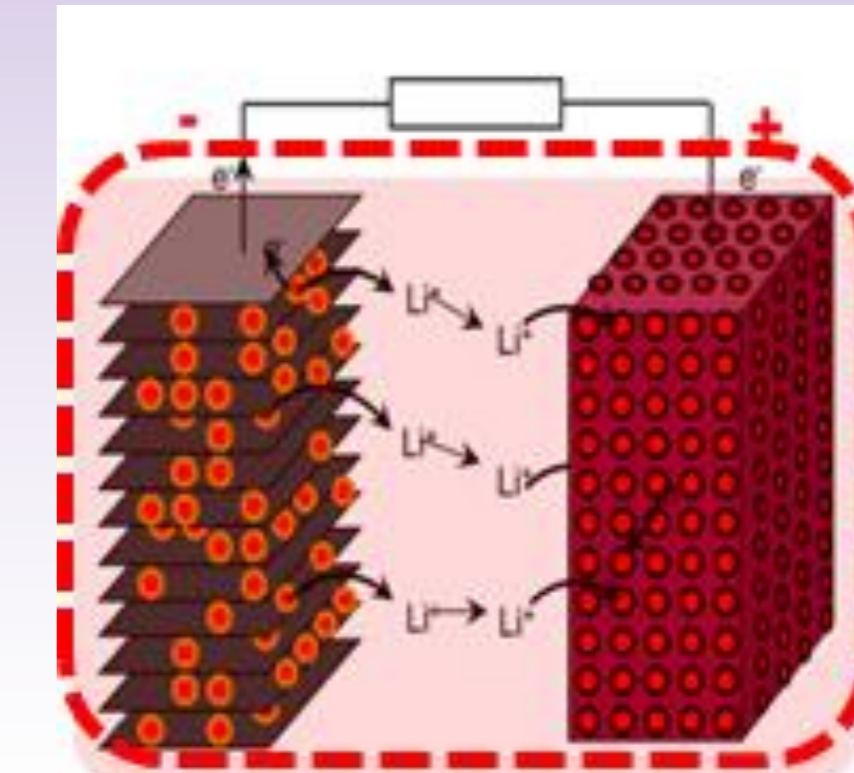
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## CONTEXT & GOAL

- **Li-ion rechargeable batteries** are currently the preferred solution to store electrical energy.
- Many incidents on different applications are related to **battery safety**.
- **The thermal runaway** has been identified as a major safety concern with Li-ion batteries on their full value chain<sup>1</sup>.

➔ Develop and validate physical and 3D model of Li-ion battery electro-thermal behavior nearby thermal runaway conditions, for a better understanding of phenomena as basis for improved engineering.

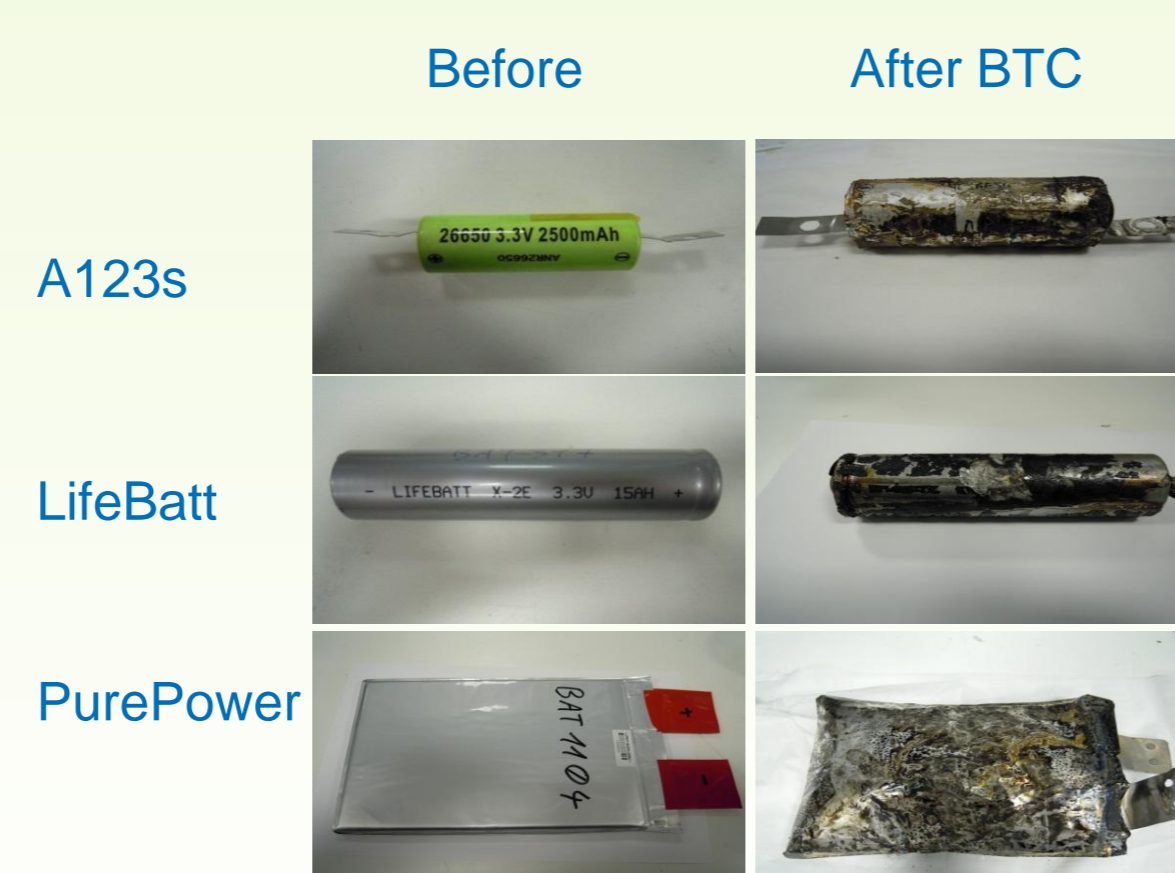
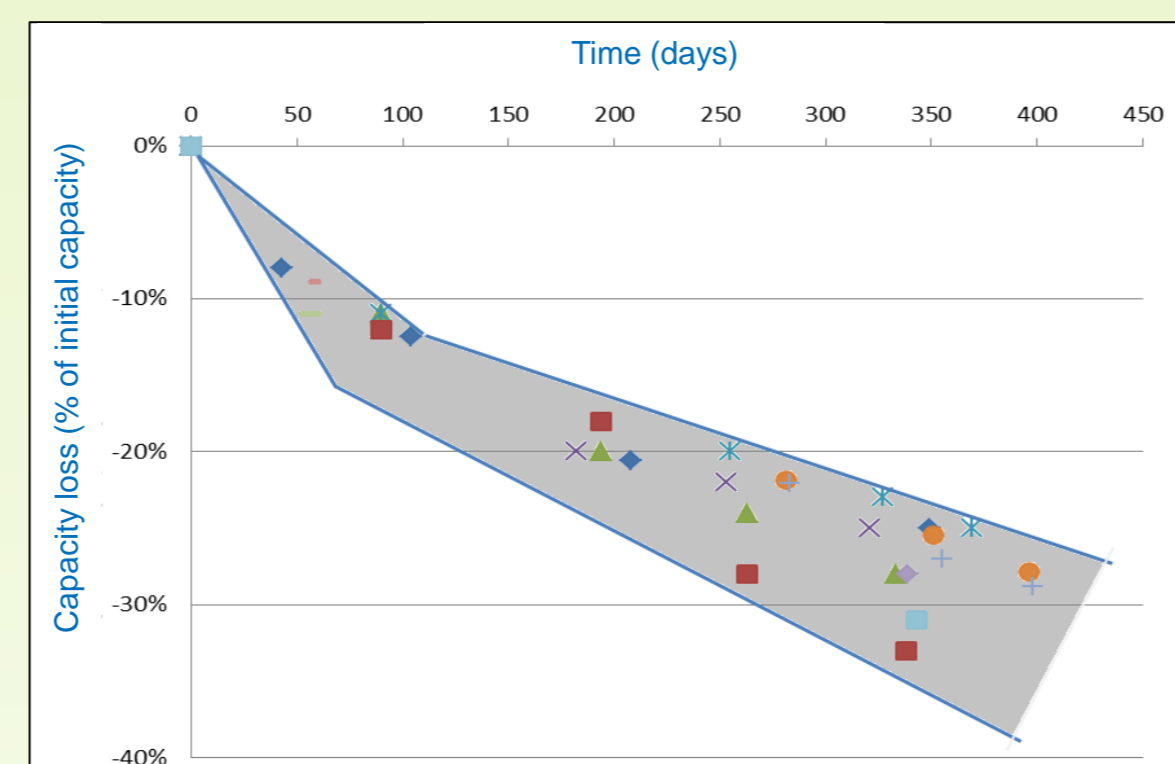


Prada et al, VPPC 2010

## COUPLED MODELING/EXPERIMENTAL APPROACH

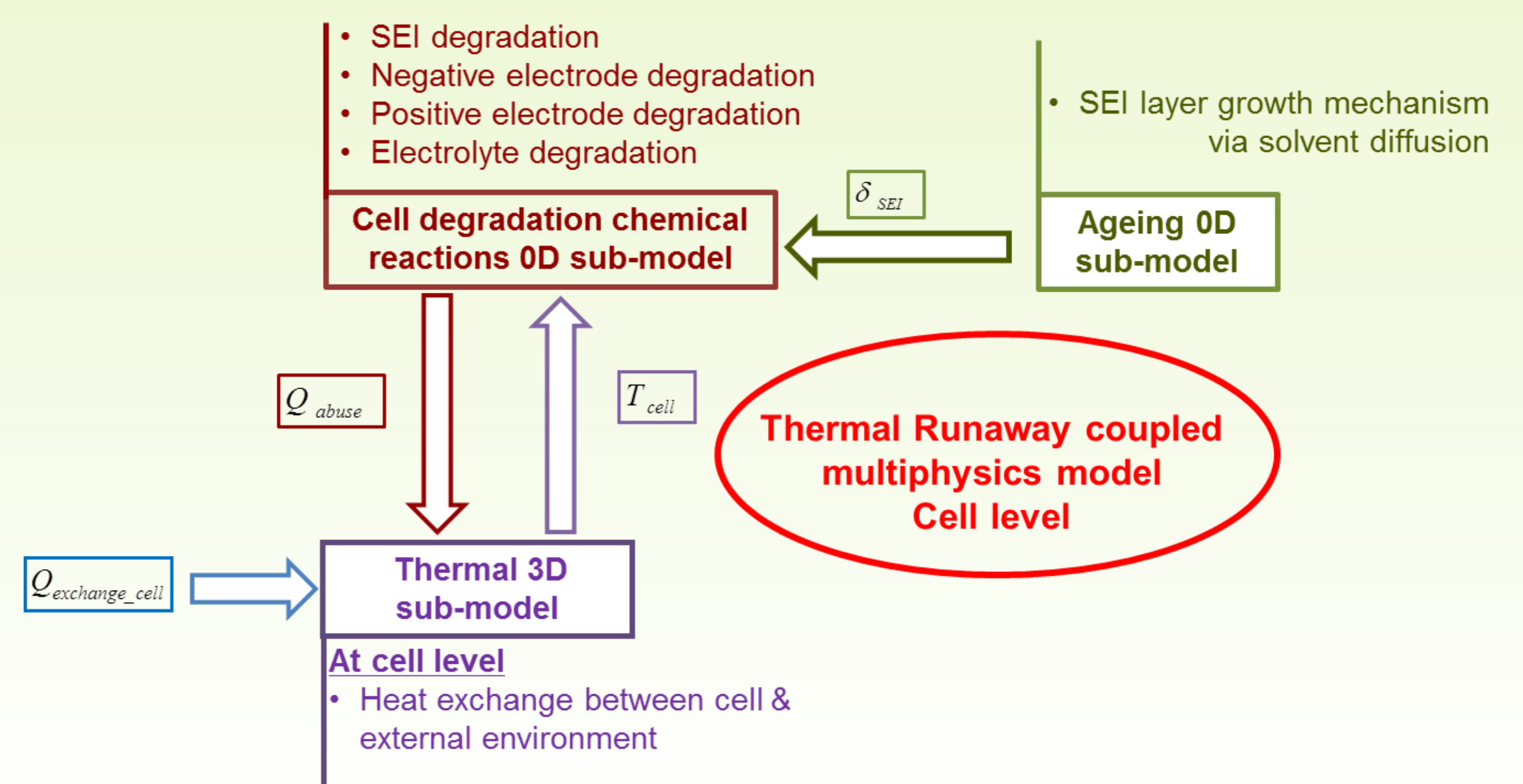
### Experiments

- Choice of 3 relevant technologies
  - 2 LFP/C cells
  - 1 NMC/C cell
- Calendar aging of cells
  - Accelerated aging
    - @ high State of Charge (SOC): 100%
    - @ high Temperature : 60 ° C
  - In order to reach 2 aging targets:
    - 10 % of capacity loss
    - 30% of capacity losses
- Abusive tests
  - Heat-Wait and Search on Battery Testing Calorimeter (BTC) device for model calibration and validation



### Modeling

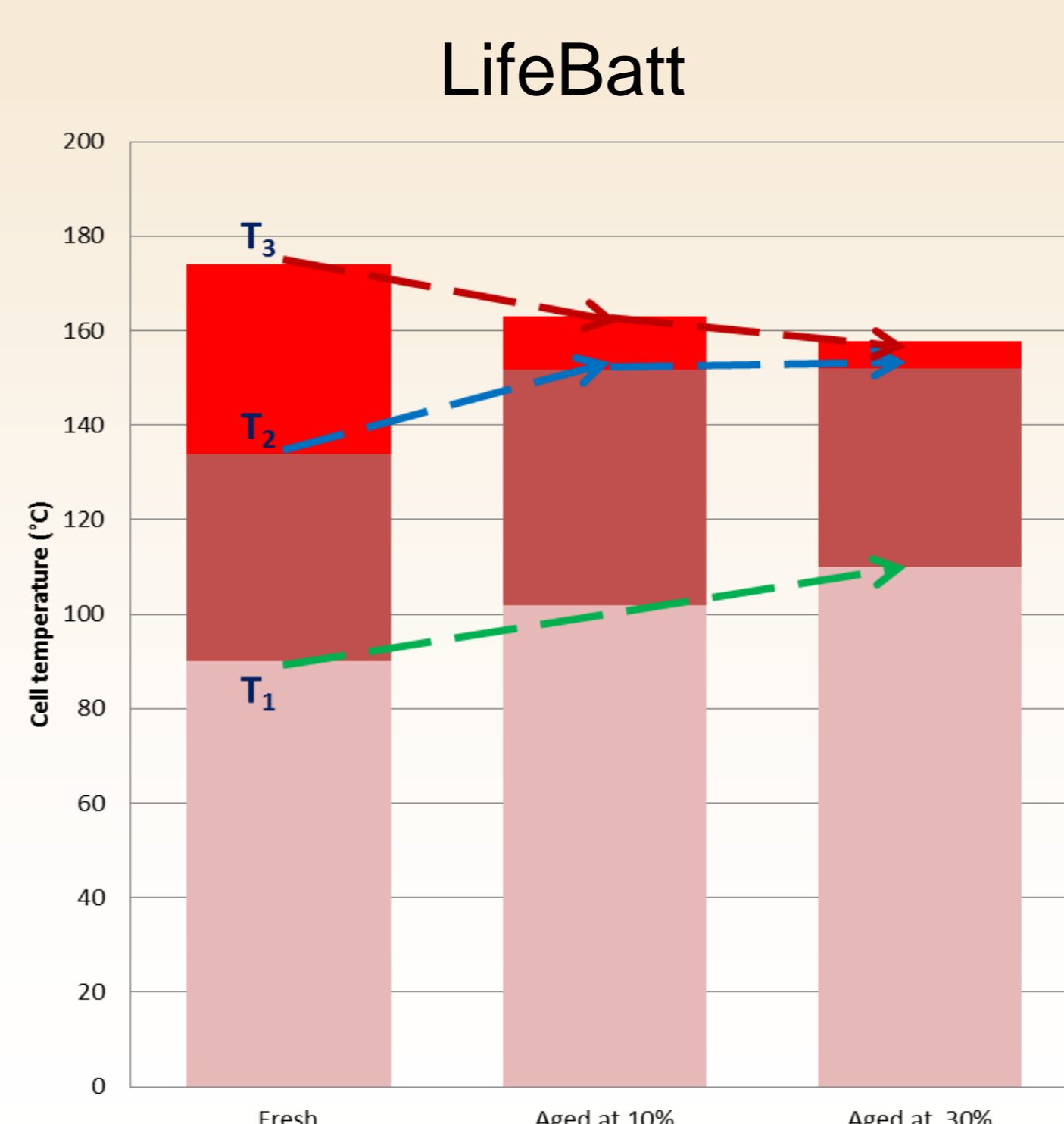
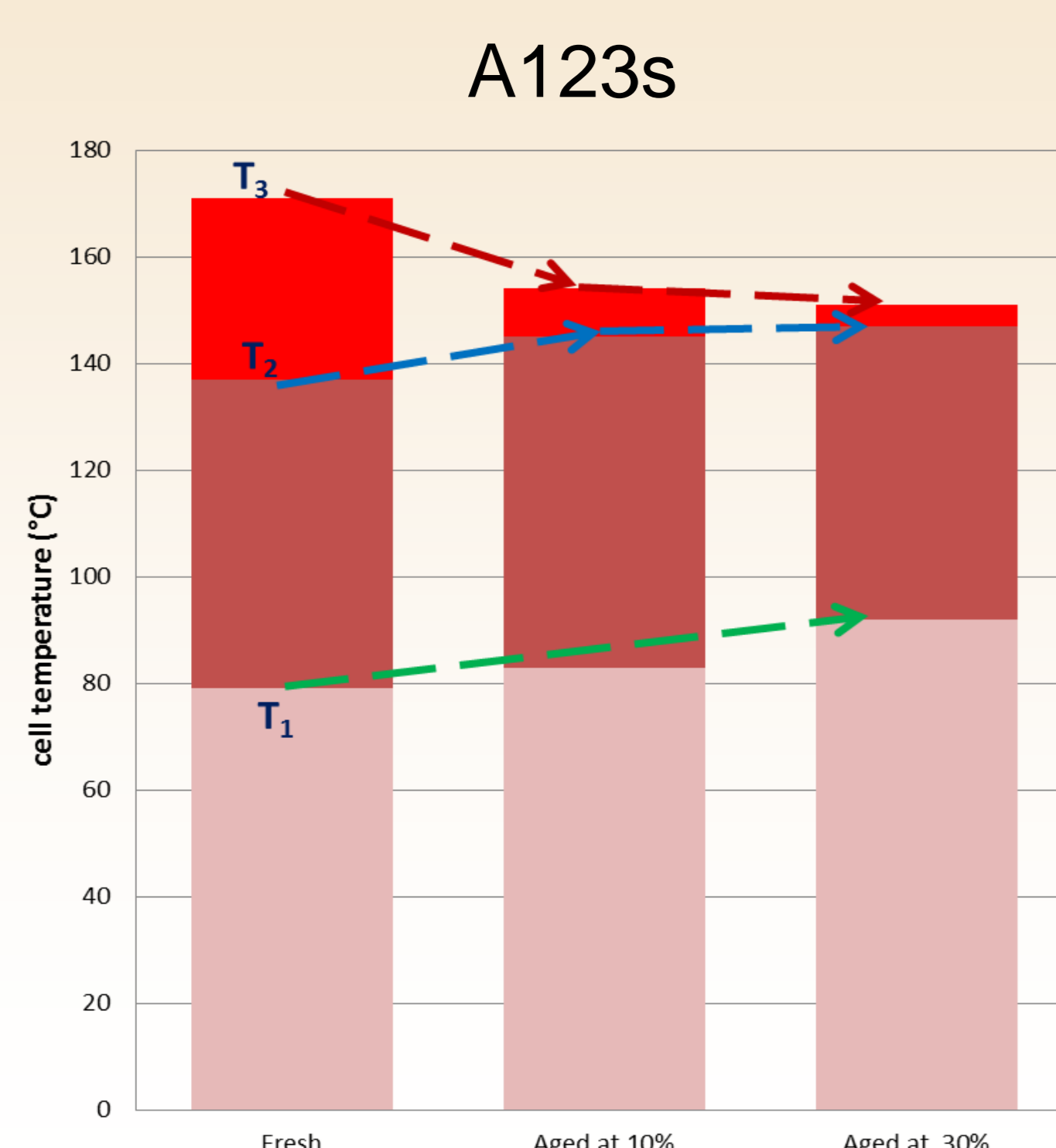
- Coupling of 3 submodels
  - 3D thermal model
  - Static aging submodel
    - Taking into account the formation of a SEI layer on the negative electrode
  - 0D cell chemical degradation model
    - Based on the four main degradation mechanisms



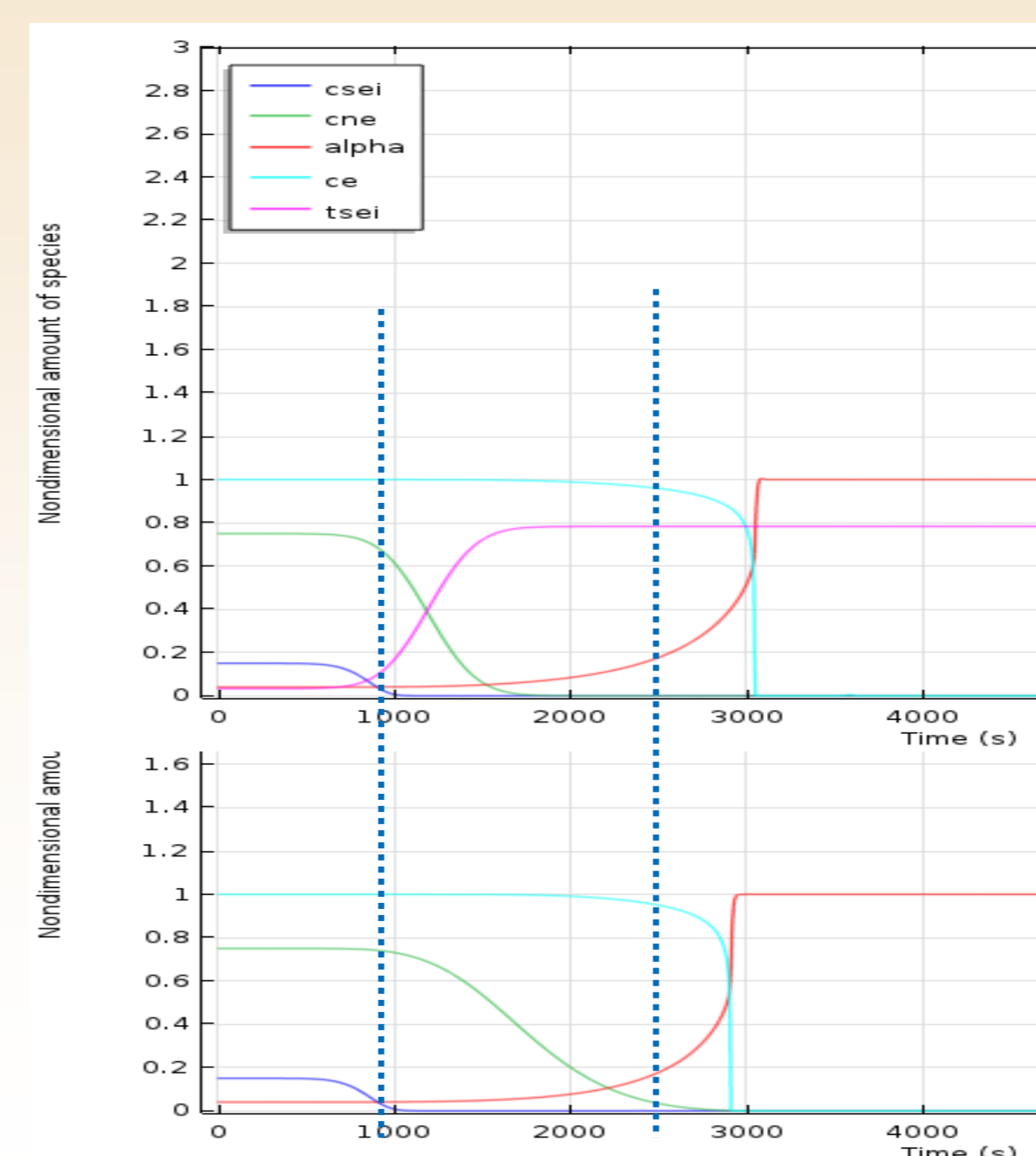
## RESULTS

- Evidence of 3 key temperatures on BTC tests for all cells:
  - T<sub>1</sub> : First exothermal reaction / end of safe phase
  - T<sub>2</sub> : Fusion of the separator
  - T<sub>3</sub> : Thermal runaway

- Stade3 "Accelerating TR"
- Stade2 "Self heating"
- Stade1 "Safe"



- Using of modeling to further discuss the experiments:
  - First exothermal reaction posponed in aged cells
    - Passivation effect of the SEI layer formed during aging
    - The second degradation reaction is slower



Fresh A123s cell

Aged A123s cell (30% capacity fade)

## CONCLUSIONS AND PERSPECTIVES

- An original experimental/modeling approach was developed to understand the effect of aging on Li-ion batteries safety
- the coupled thermal runaway model was validated at the cell level on BTC tests at INERIS testing platform
- the validated model was used in order to discuss why aged cells appear safer than fresh ones
- Further work has to be done to take into account cycling aging:
  - Study of safety degradation linked to cycling aging (Li plating...)
  - Study of high energy cells with up-to-date Li-ion technologies

[1] S. Abada et al., "Safety focused modeling of lithium-ion batteries: A review," *J. Power Sources*, vol. 306, pp. 178–192, 2016.

