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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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Tesla Model S,
USA, 2013



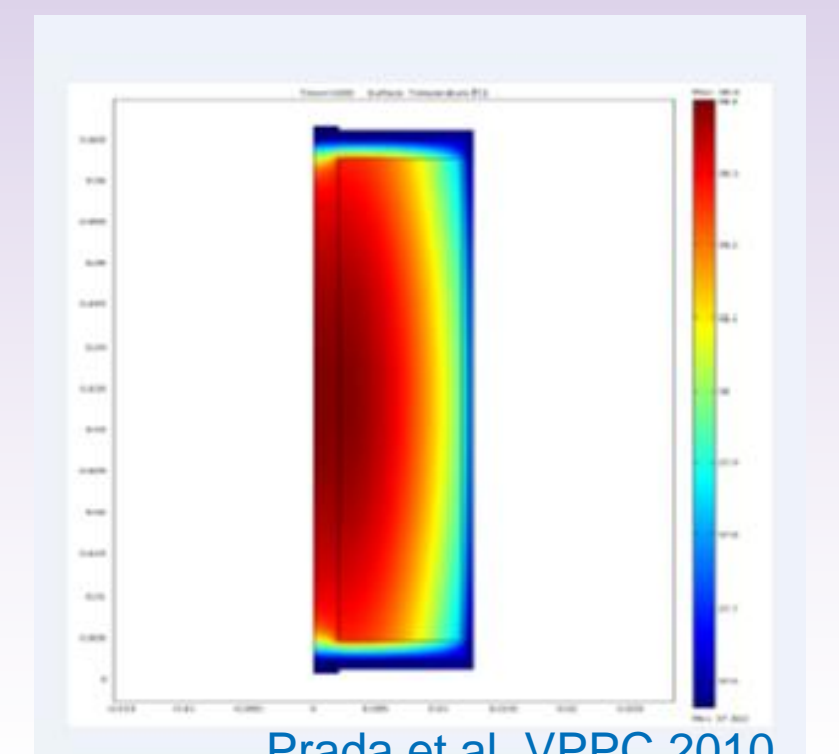
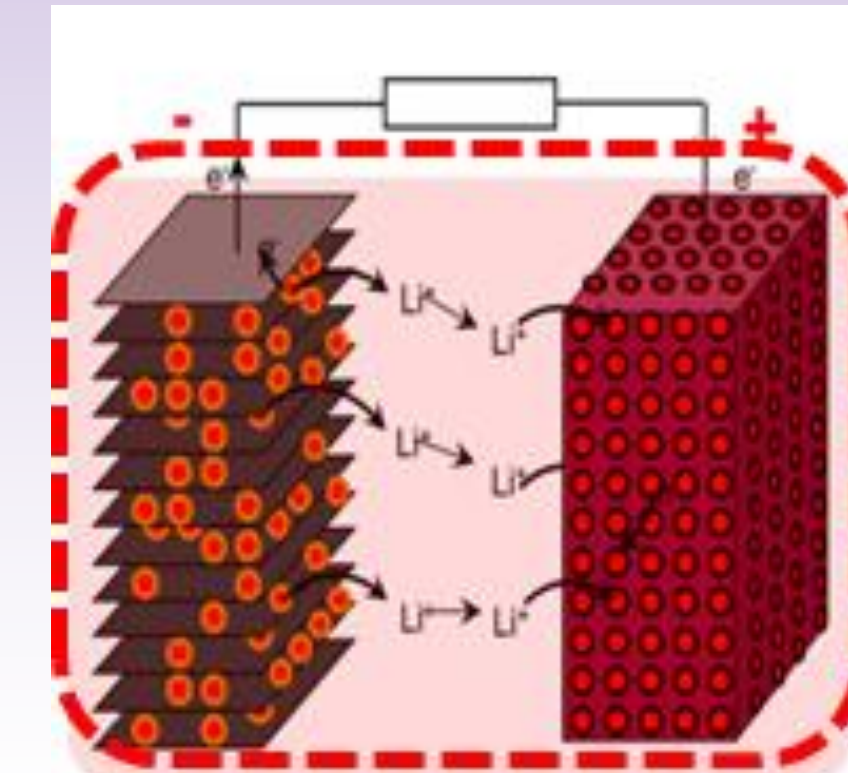
Boeing 787 Dreamliner
Japan Airlines, 2013



Cycling site,
UK, 2008

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 chain¹.



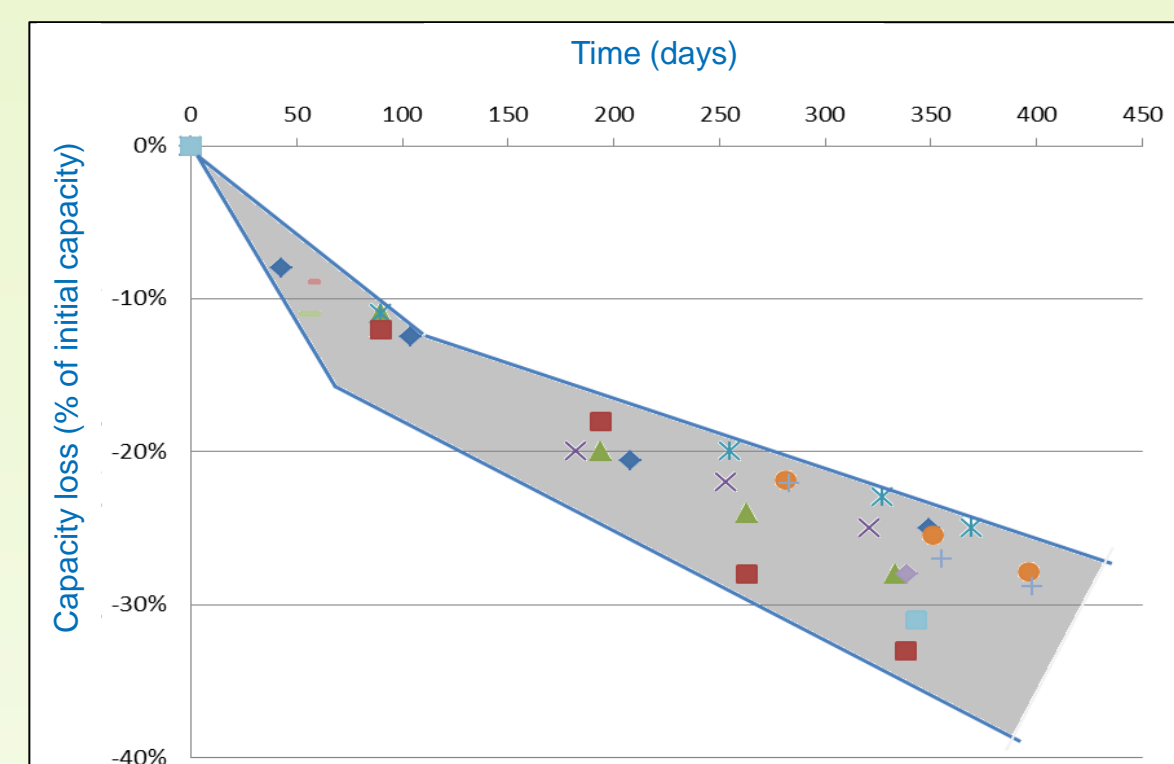
Prada et al, VPPC 2010

➔ 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.

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

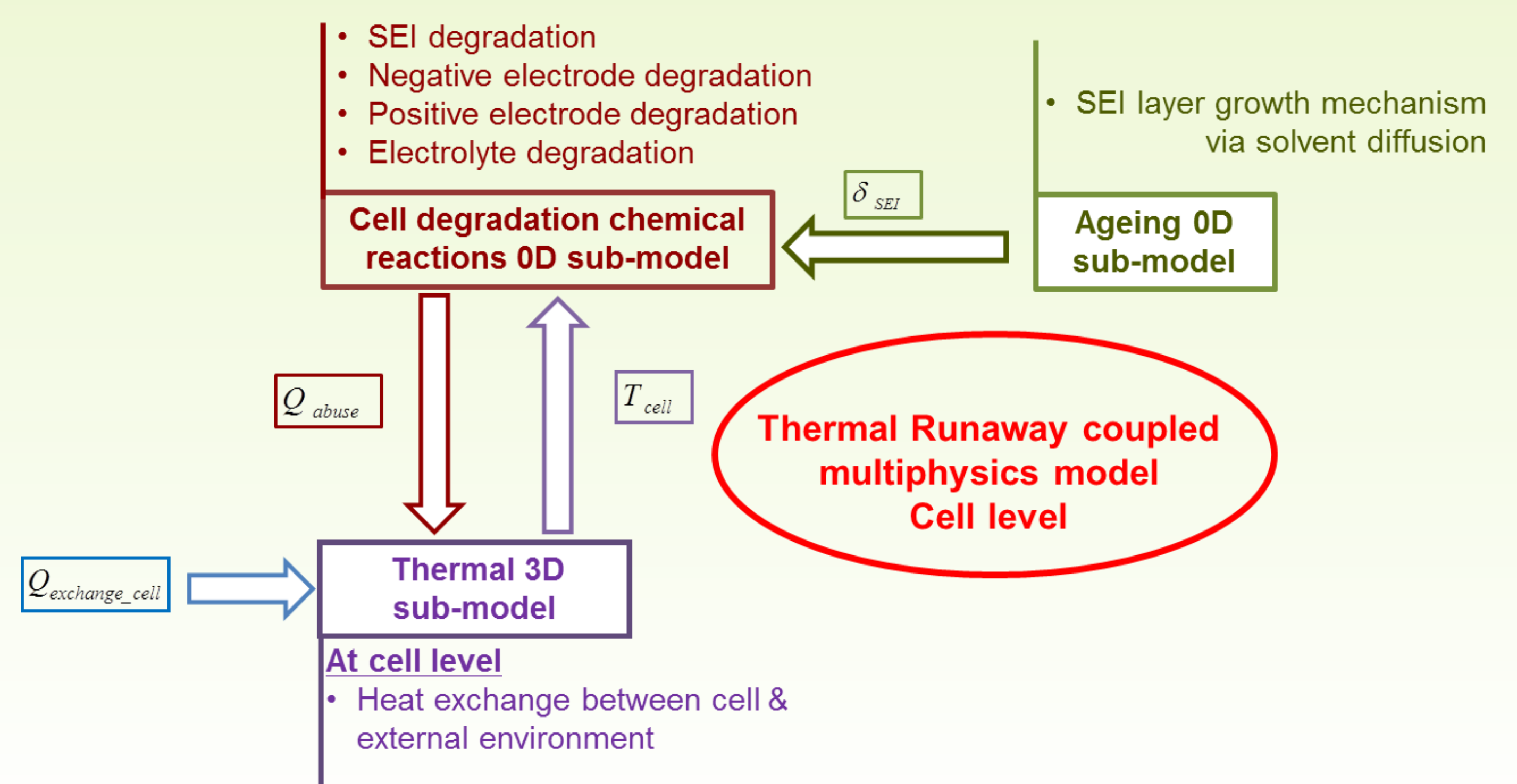


- Abusive tests
 - Heat-Wait and Search on Battery Testing Calorimeter (BTC) device for model calibration and validation



Modeling

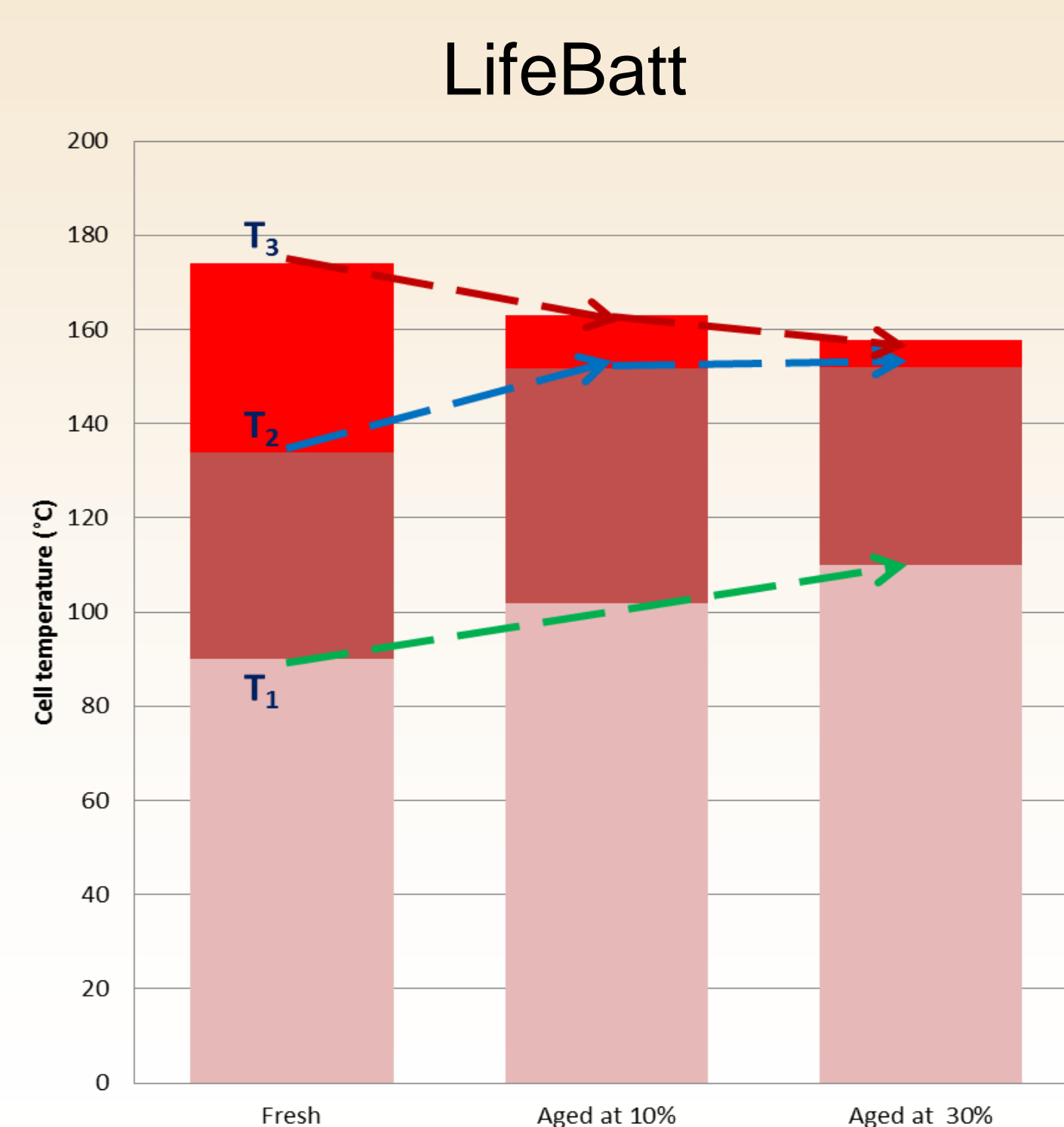
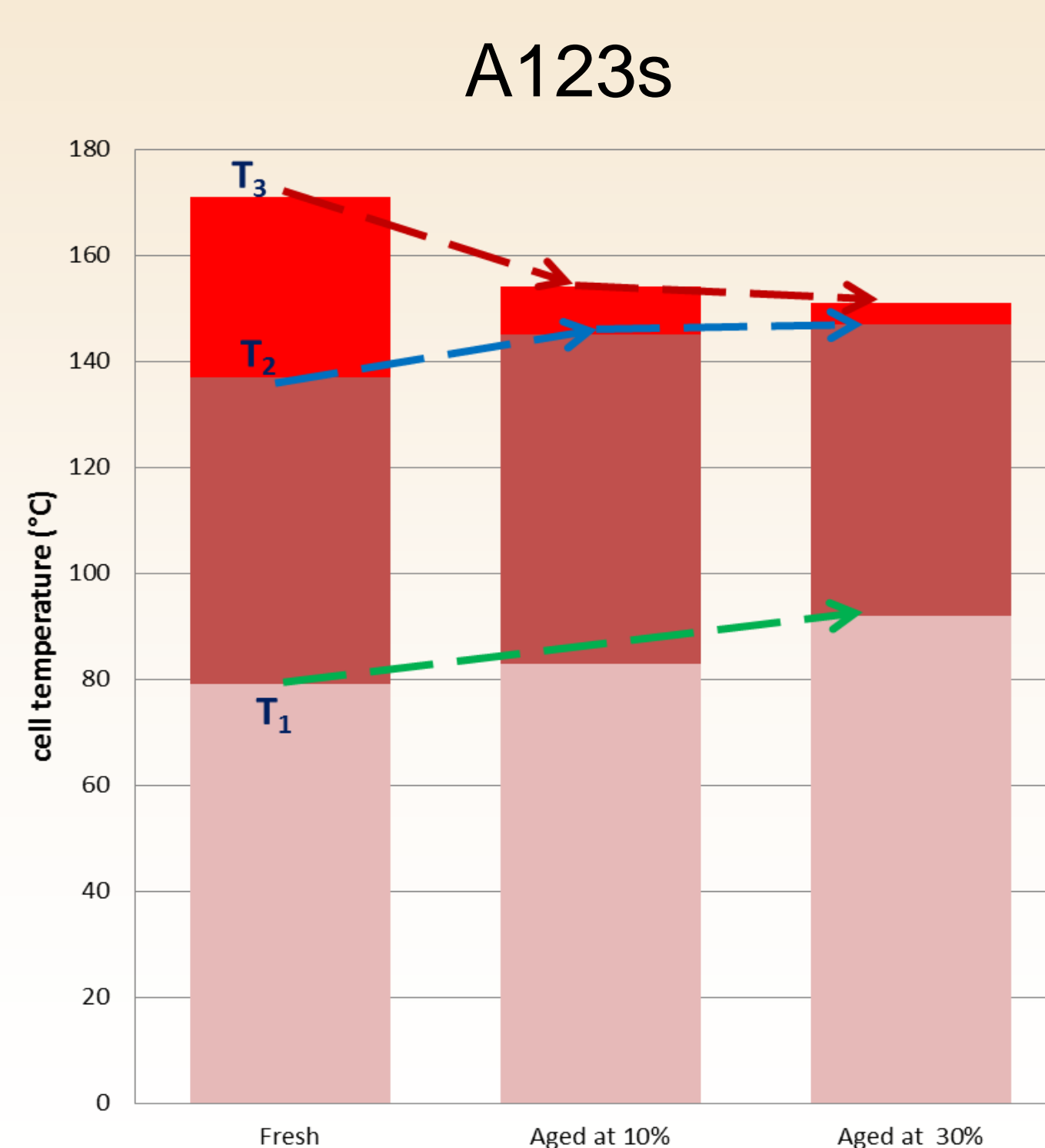
- Coupling of 3 submodels
 - 3D thermal model
 - Static aging submodel
 - Taking into account the formation of a SEI layer on the negative electrode
 - 0D cell chemical degradation model
 - Based on the four main degradation mechanisms



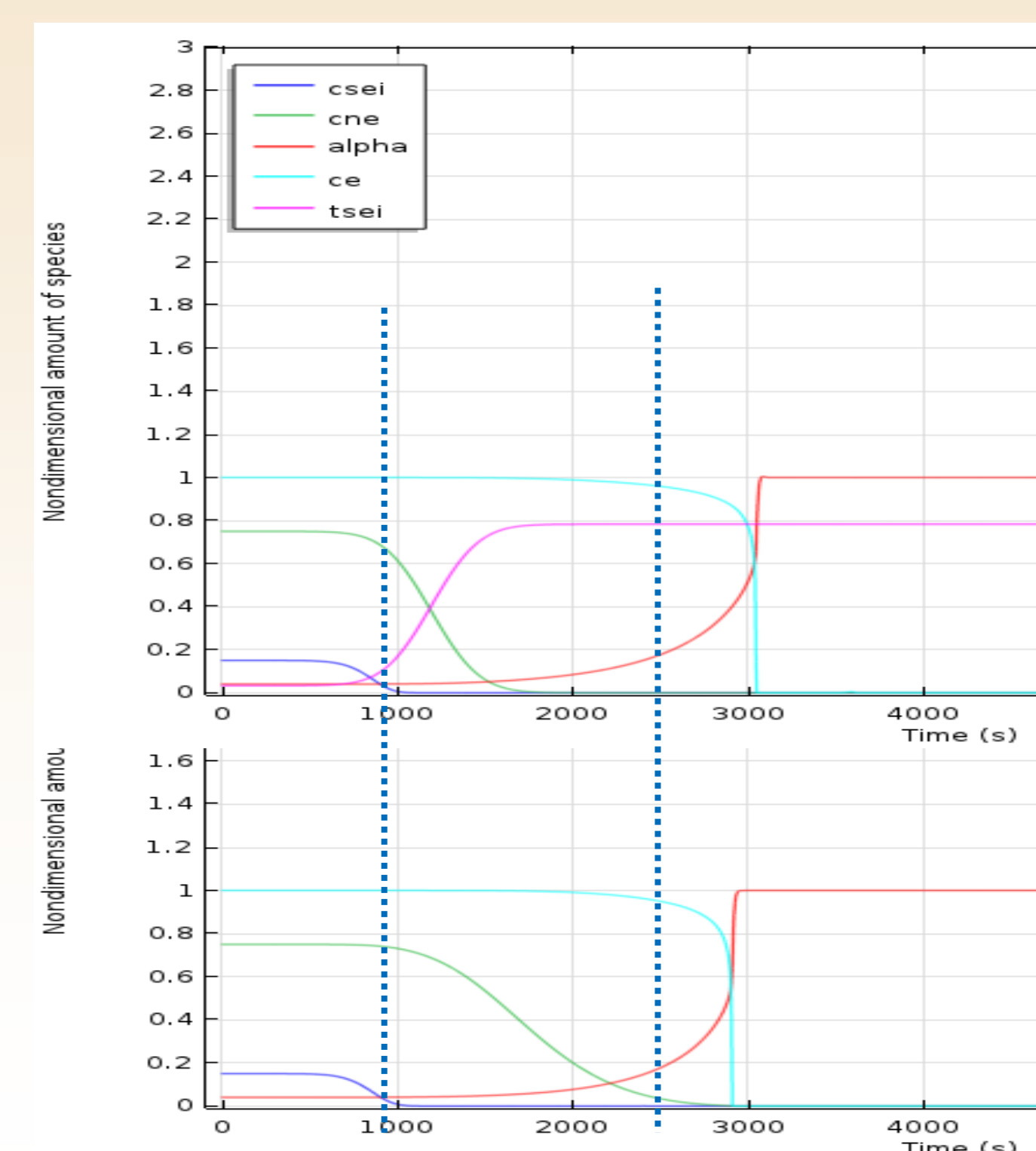
RESULTS

- Evidence of 3 key temperatures on BTC tests for all cells:
 - T₁ : First exothermal reaction / end of safe phase
 - T₂ : Fusion of the separator
 - T₃ : 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.