3D thermal simulation of a buffer battery for an industrial fuel cell vehicle

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e-Mersiv

e-Mersiv "why"

Our mission: accelerate EV transition thanks to high performance batteries

1. **Immersion cooling** to reach very high C-rates
2. **Advanced BMS** to enable higher safety and longer lifetime

e-Mersiv batteries to be used in BEVs and HEVs (including FCEVs):

- Whenever the **Power to Energy ratio is higher than 3**
- Whenever the **ultra fast charging in less than 10 minutes** is required
- Whenever conditions are **severe: hot/cold weather and long lifetime**

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e-Mersiv in a nutshell

- **Joint Venture** of:
  - **EXOES**, expert in thermal management systems for vehicles
  - **Startec Development**, expert in batteries and BMS
- 2x locations in **Bordeaux** area
- A task force of **50x people**

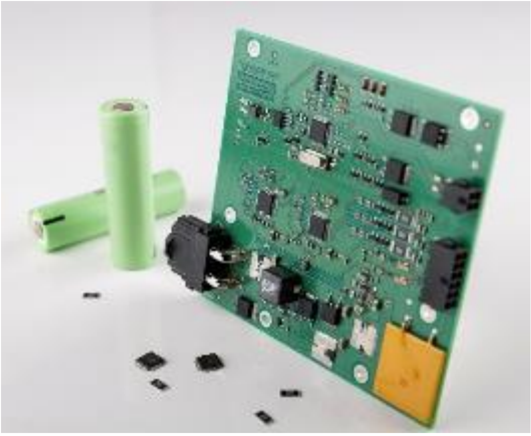
- Internal capabilities:
  - BMS, battery pack & cooling systems design
  - Manufacturing
  - Tests: full performance, abusive and aging

- Seasoned team
  - 20-year experience in Li-ion batteries
  - 11-year experience in fluids used for thermal management

Last achievements of the team

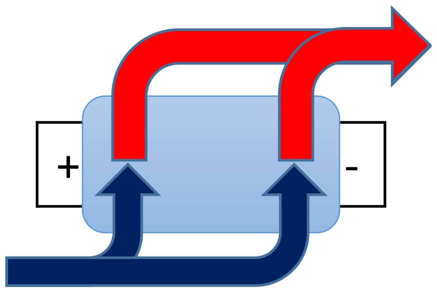
- ✓ Complete battery packs using different types of cells: form factors & electrochemistry: Li-Ion / Na-Ion / LTO…
- ✓ Complete BMS development and manufacturing
- ✓ High energy or high-power battery packs developed



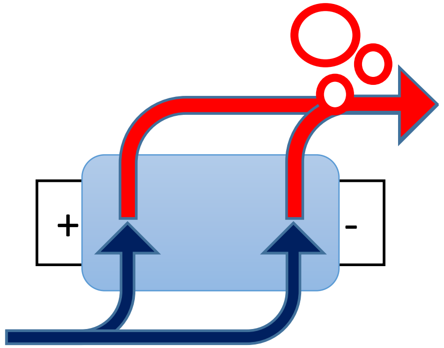


Focus on Battery immersion cooling

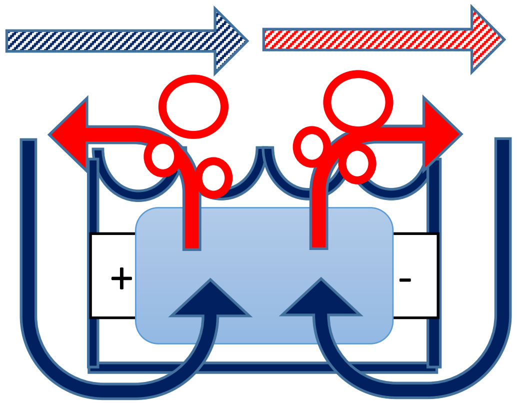
A large variety of technologies



Pumped liquid



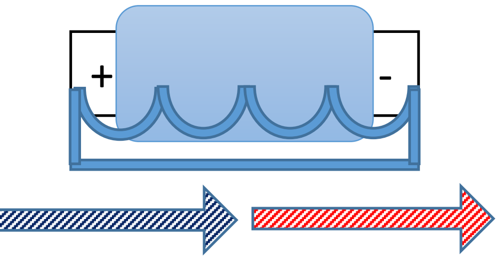
Pumped-2-phase



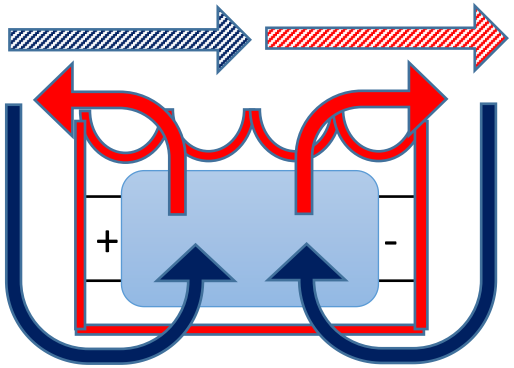
Pool boiling or vapor chamber

Criteria to make a choice:

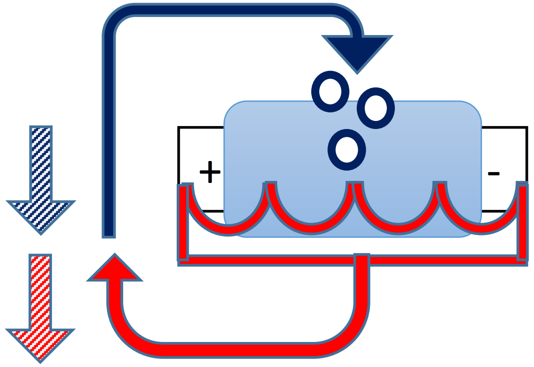
- Cost
- Weight
- Cooling loop
- System performances
- Manufacturing process
- Etc.



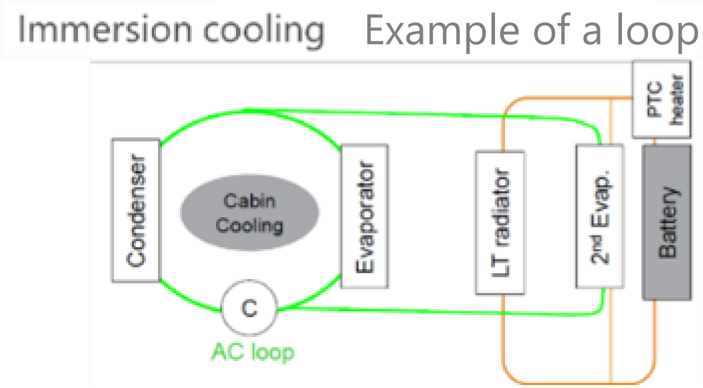
Gap filler



Static bath



Spray



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The cooling fluid

- 2x categories : Oils and refrigerants
- Some criteria are listed below to choose the right fluid after extensive tests:

Cost / kg	Density	Heat Transfer coefficient	Viscosity	Dielectric properties	GWP ODP	Water acceptance	Material compatibility

- Extract of potential fluid suppliers:

Immersion-cooled products under development

- 3x different products for 3x different markets

	details.	Peak C-rate ch. / disch.	Average C-rate	Densities At pack level	Cooling
Powerfull electric vehicles	- 230 Wh/L - designed for large batteries - Cell-to-pack - Dielectric cooling loop <40°C - NMC 21700 cells	10C / 10C	10C rms	130 Wh/kg 1,250 W/kg	Liquid
		Ex: Energy 2,15kWh Peak Power charge 21,5kW / discharge 21,5 kW			
Hybrid or Full electric racing	- 800V - Dielectric cooling loop @60°C - LCO Pouch cell	40C / 100C	40C rms	80 Wh/kg 3,400 W/kg	Pumped-2-phase
		Best trade-off between energy and power densities Ex: Energy 2,15kWh Peak Power charge 86 kW / discharge 215 kW			
Powerfull hybrid vehicles (incl. FCHEV)	- 30,000 Cycles - Attractive TCO - Air cooled possible, or water loop @25°C - LTO prismatic cell	40C / 40C	8C rms	30 Wh/kg 1,250 W/kg	Up to Pool boiling
		Best trade-off between densities and lifetime Ex: Energy 2,15kWh Peak Power charge 86 kW / discharge 86kW			

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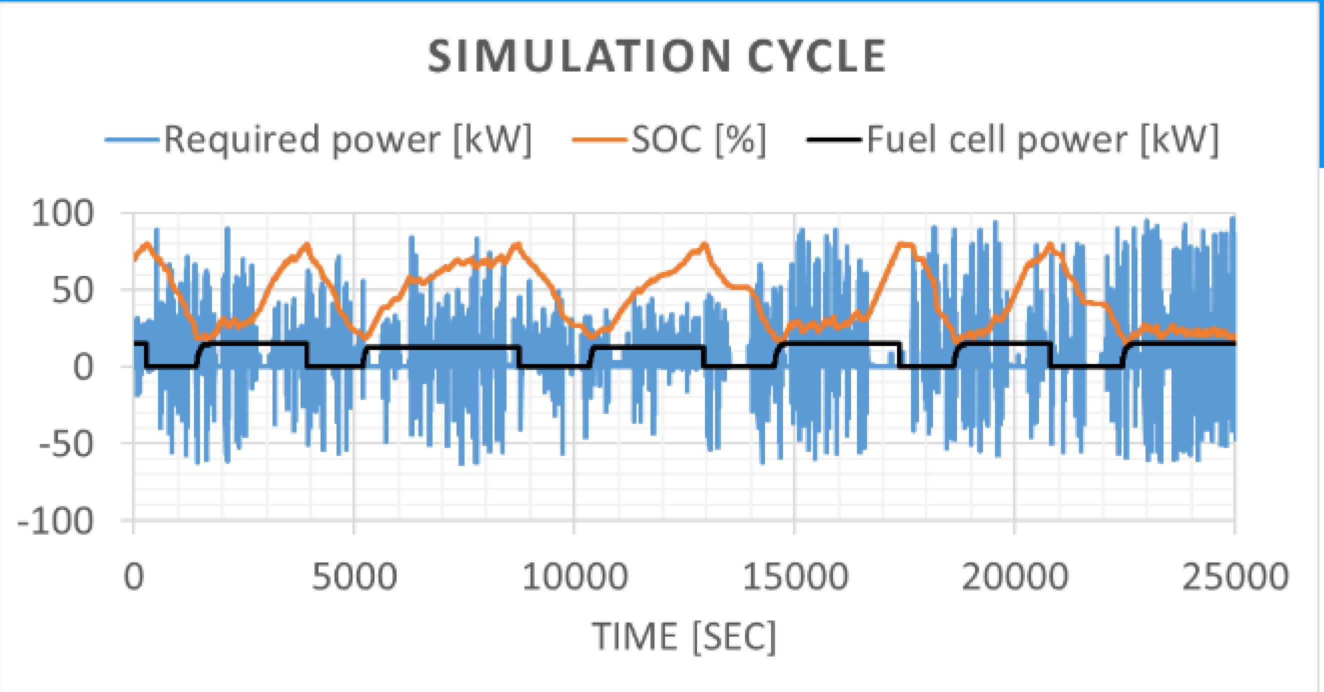
Simulation of a buffer battery for FCEVs

Use case: industrial FCEV

- An industrial vehicle running 24h/7d
- Equiped with a small fuel cell (FC)
- With repetitive power peaks (10x power of the FC)

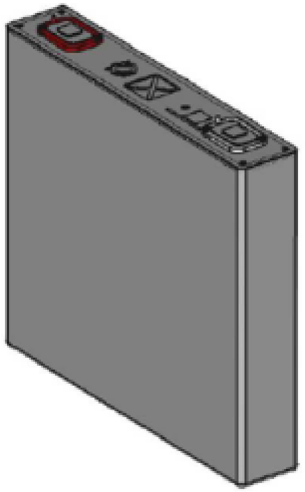
- Ratio of energy required on power is:
  - 10C peak
  - and 6C rms !

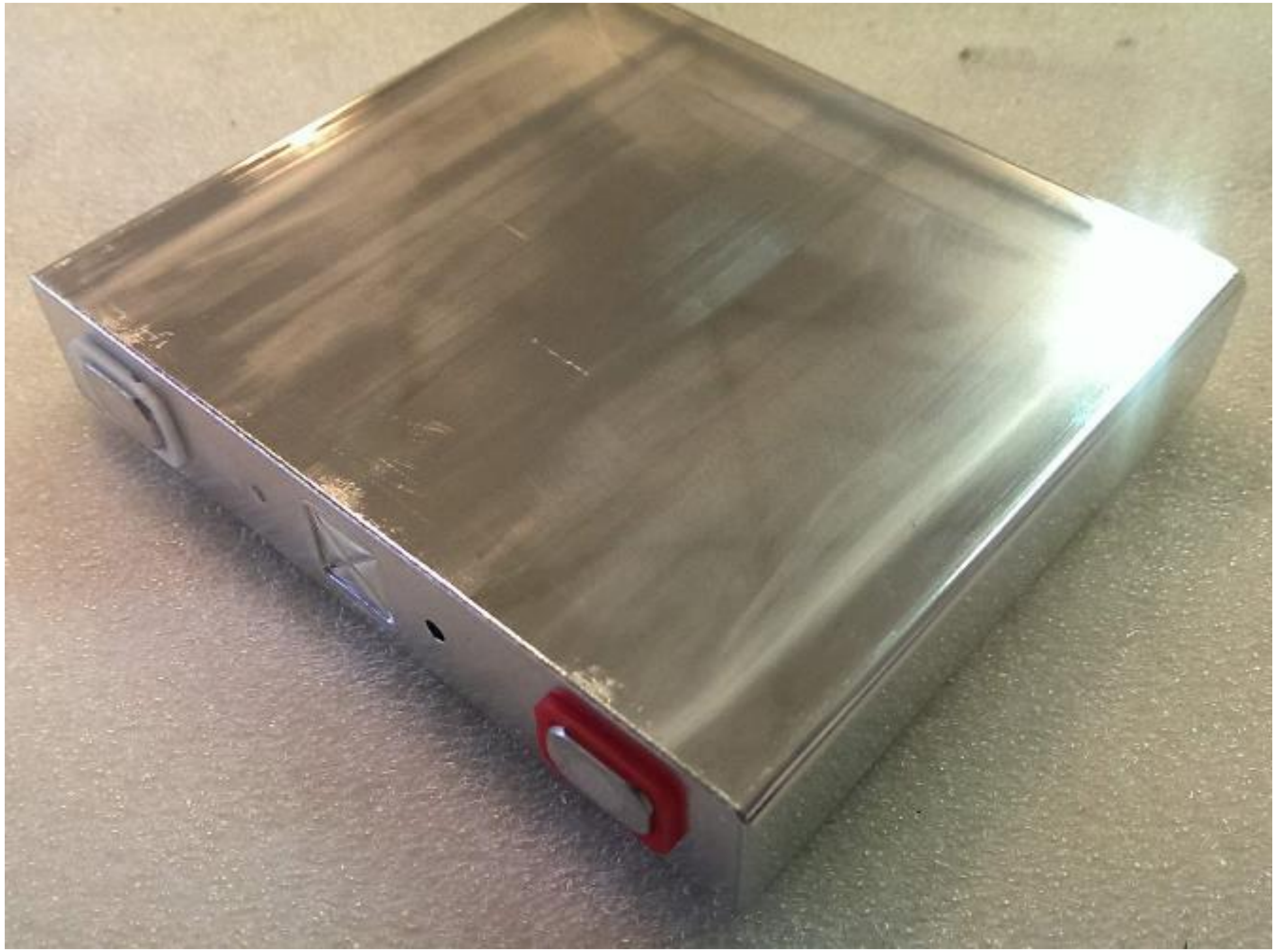
Stringent requirements on both
Lifecycles & Thermal performances



The cell: LTO prismatic

- LTO 23Ah 2.3V
- LxlxH = 115x22x105 mm
- 100 Wh/kg
- Up to 20C rms
- 1000A for 1sec
- 15,000 cycles (EOL 80%, 25°C, 100% DOD)

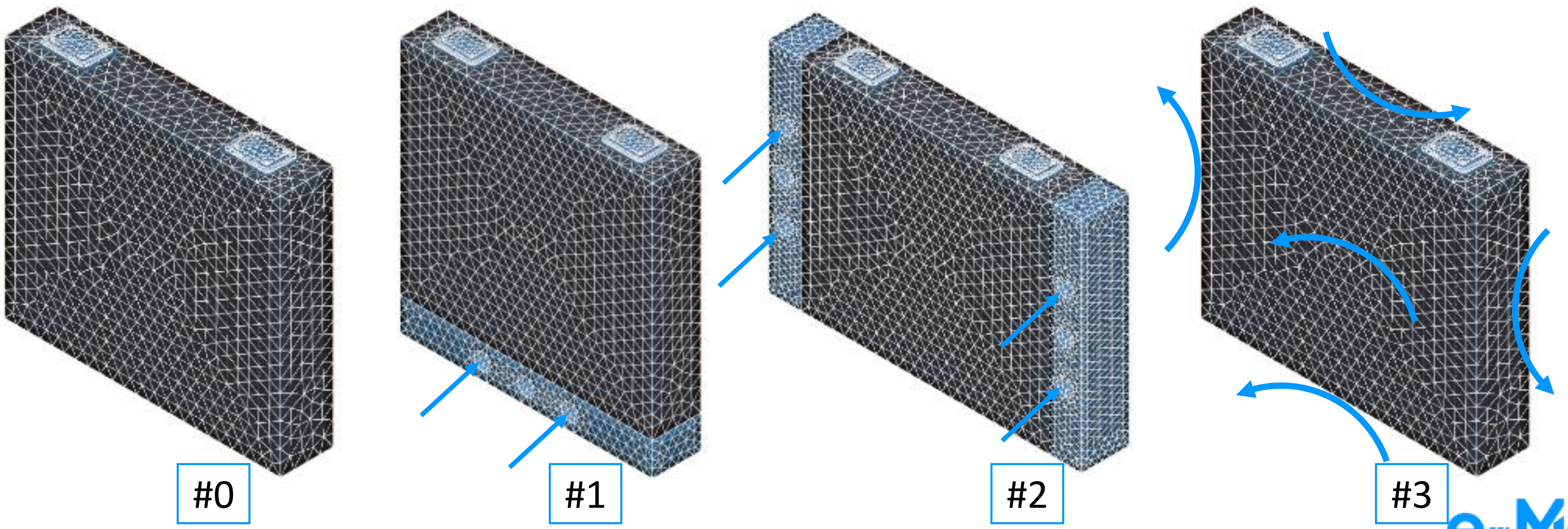




Cooling options simulated

- we defined the following scenarios for the cooling architecture :
- Cooling fluid inlet : 25°C
- Ambient temperature : 25°C
- Initial temperature : 25°C

Scenario	Cooling configuration
#0	No cooling
#1	Bottom cold plate
#2	2x lateral cold plates
#3	Full immersion



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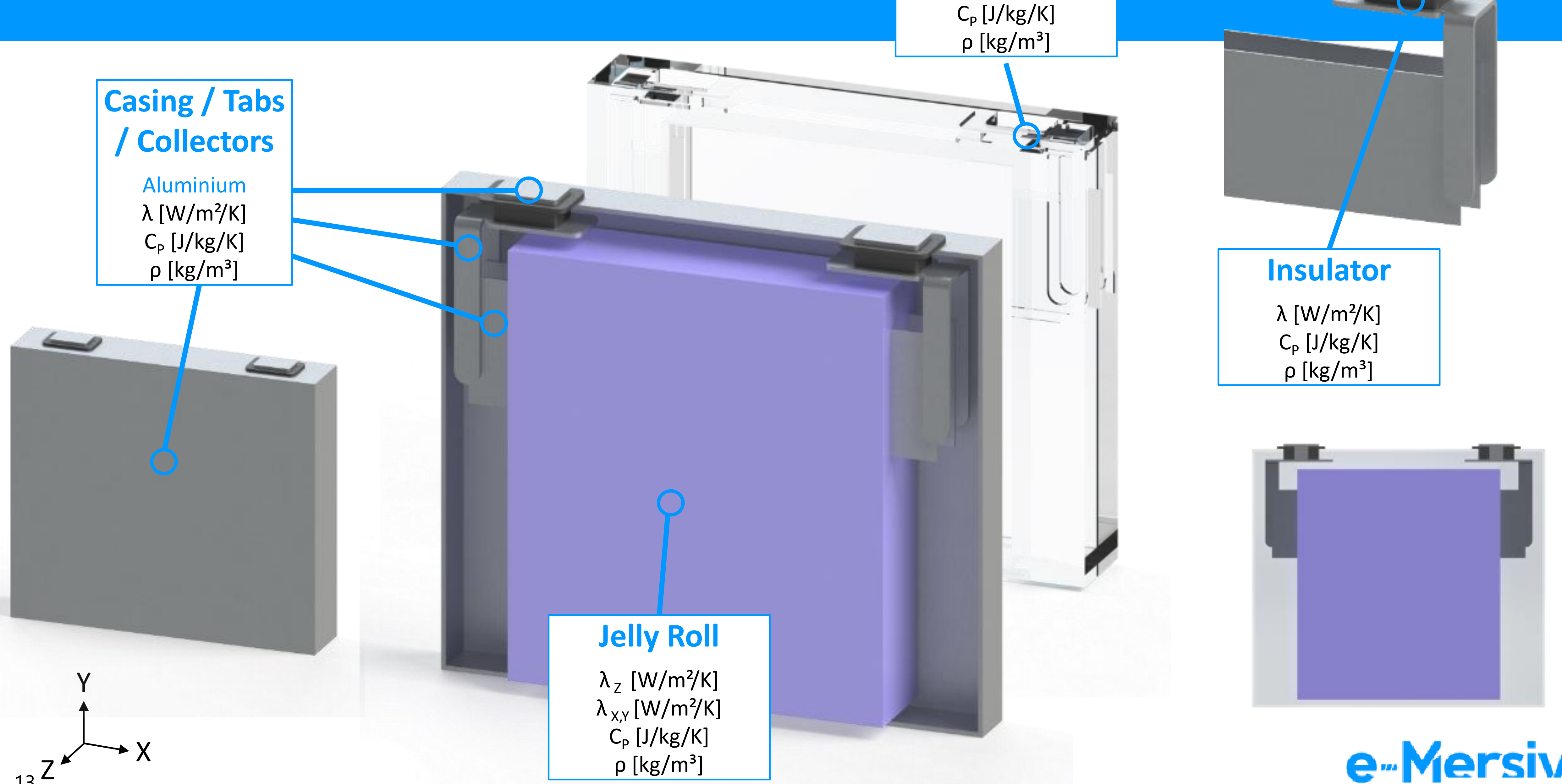
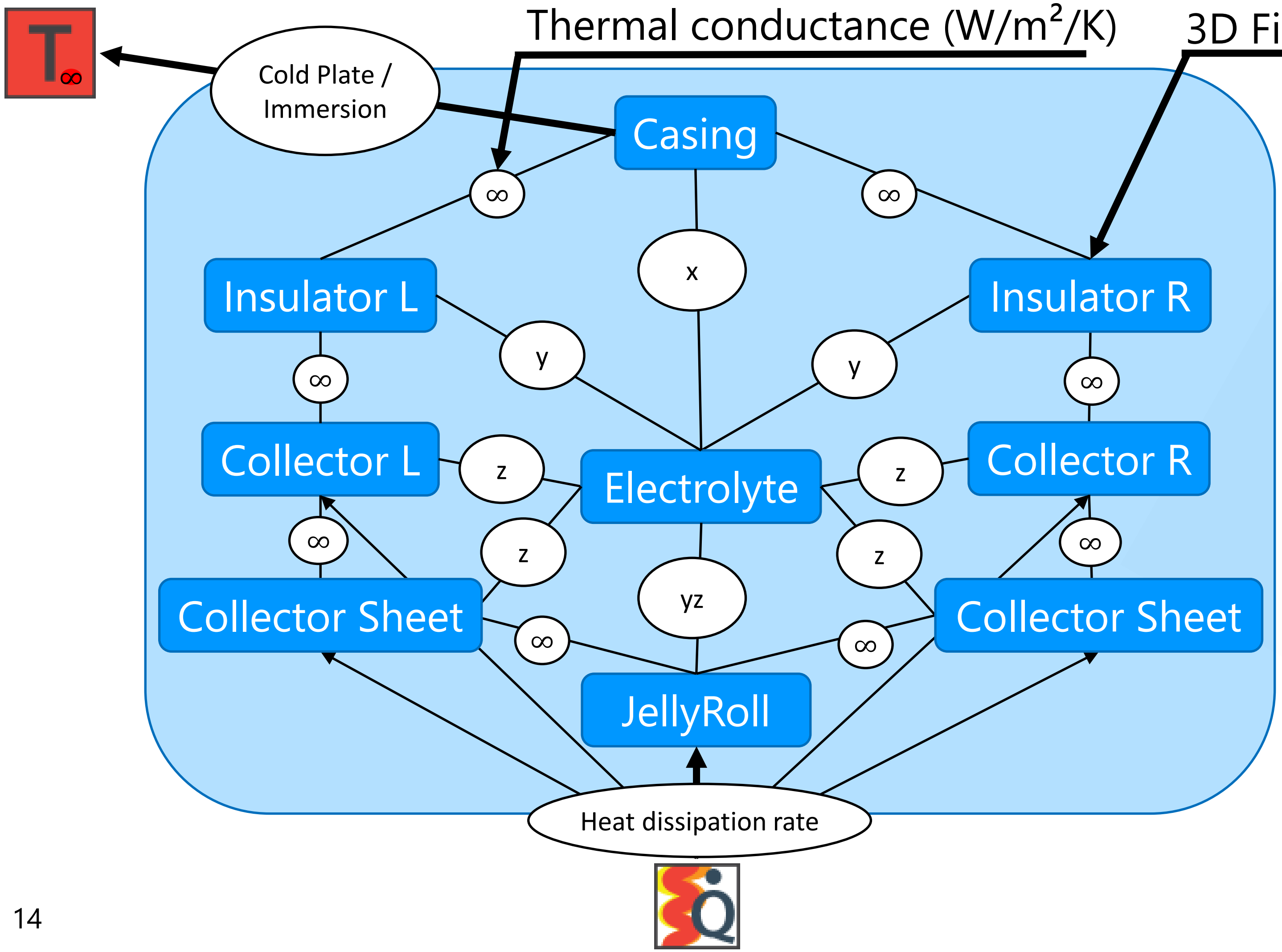
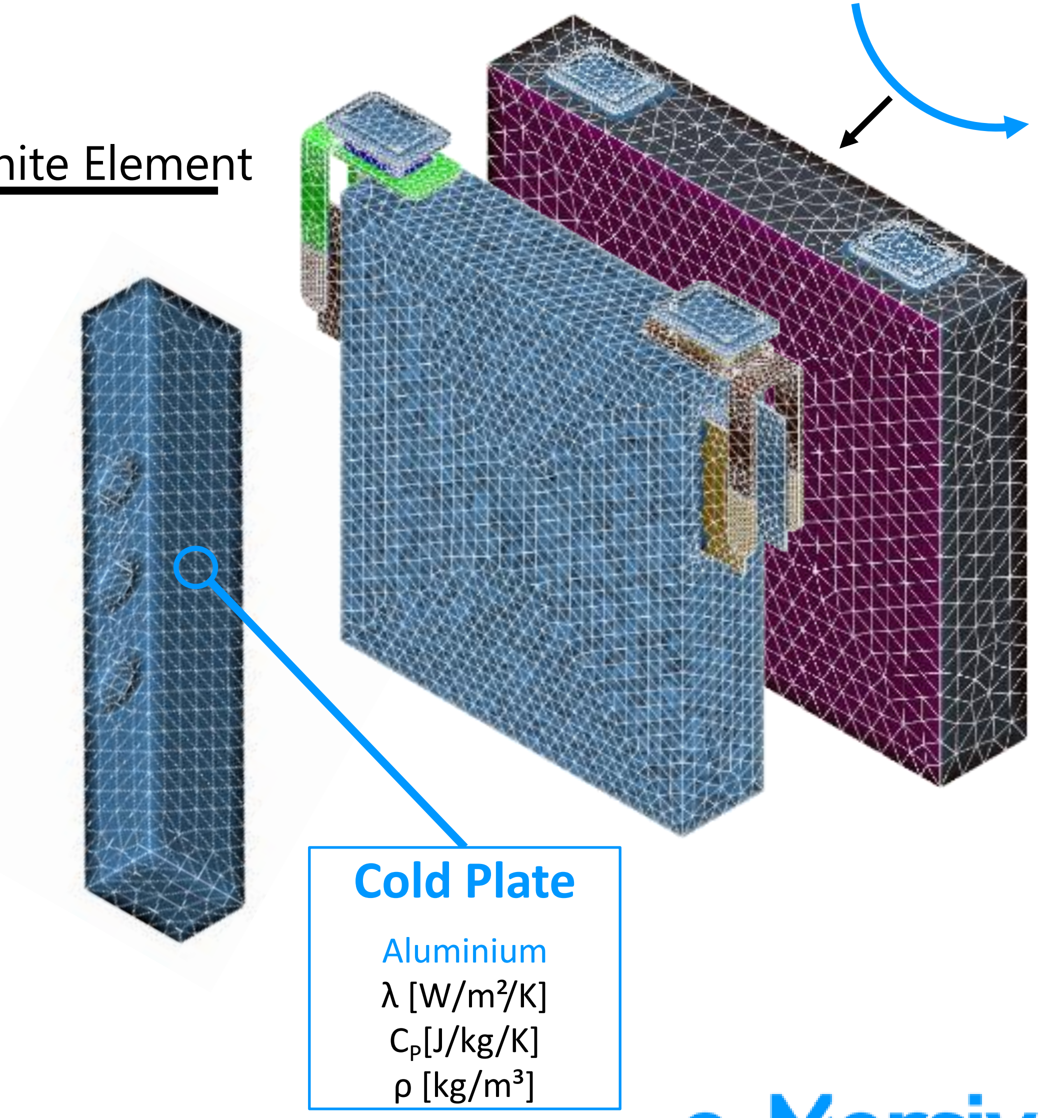
The cell model



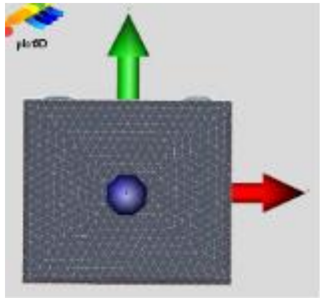
The cell model details

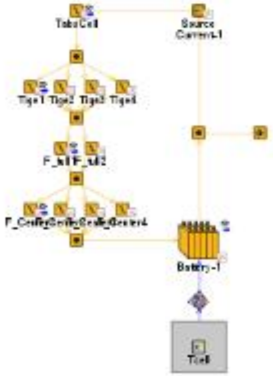
- Conductive components are meshed (GEM 3D)
- Insulators are modeled with a single conductance

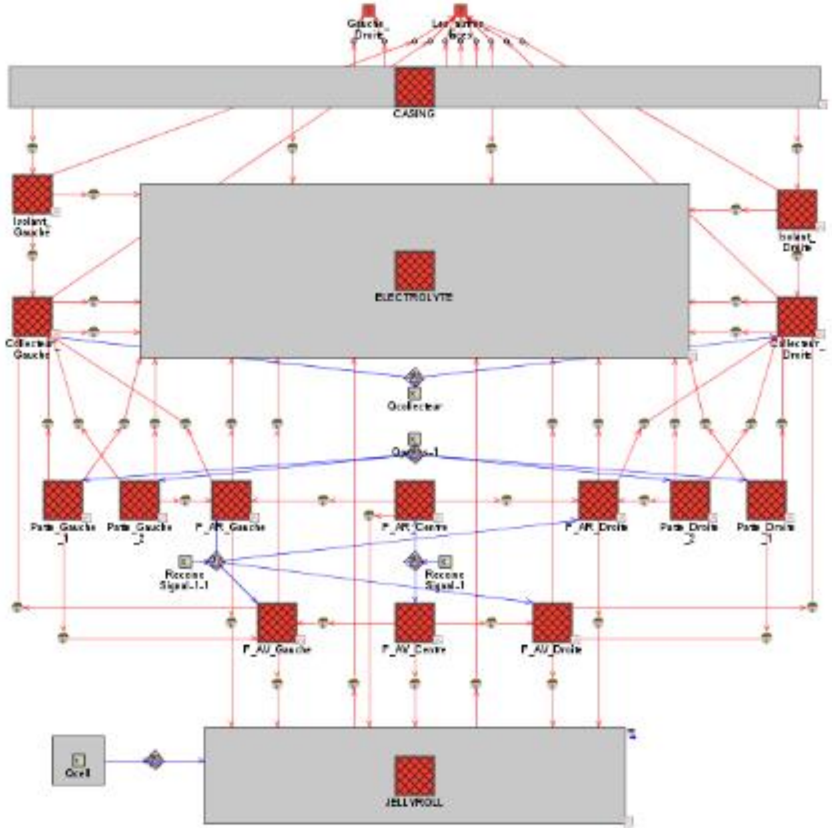




The complete model





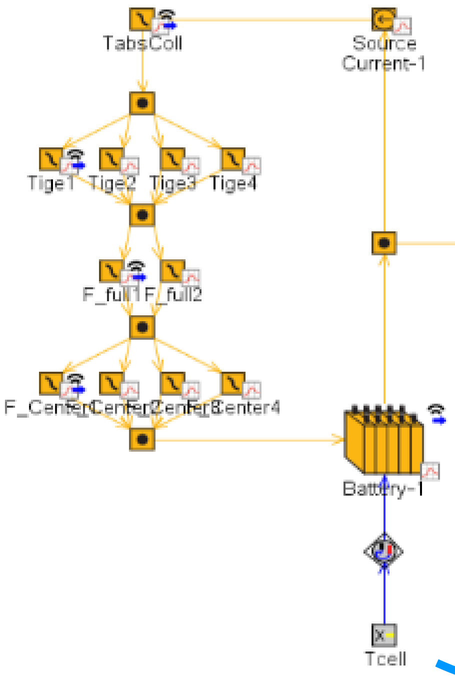


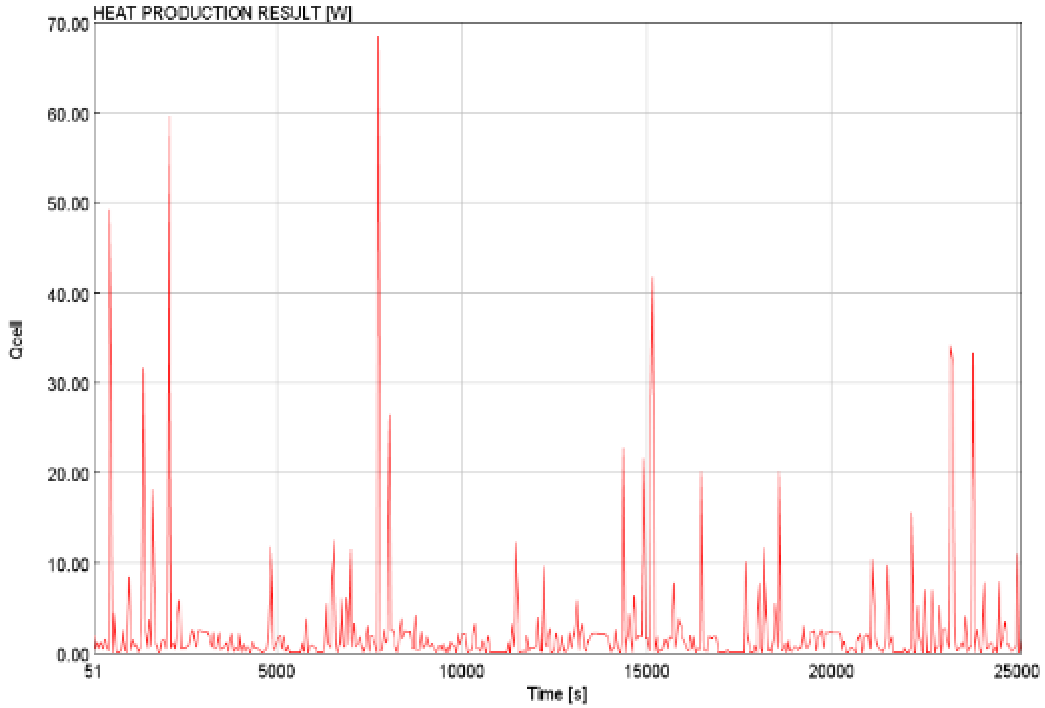
- The system is simplified to a single cell
- The external heat transfer is modeled by a constant heat transfer coefficient h.
- The busbar connection is neglected

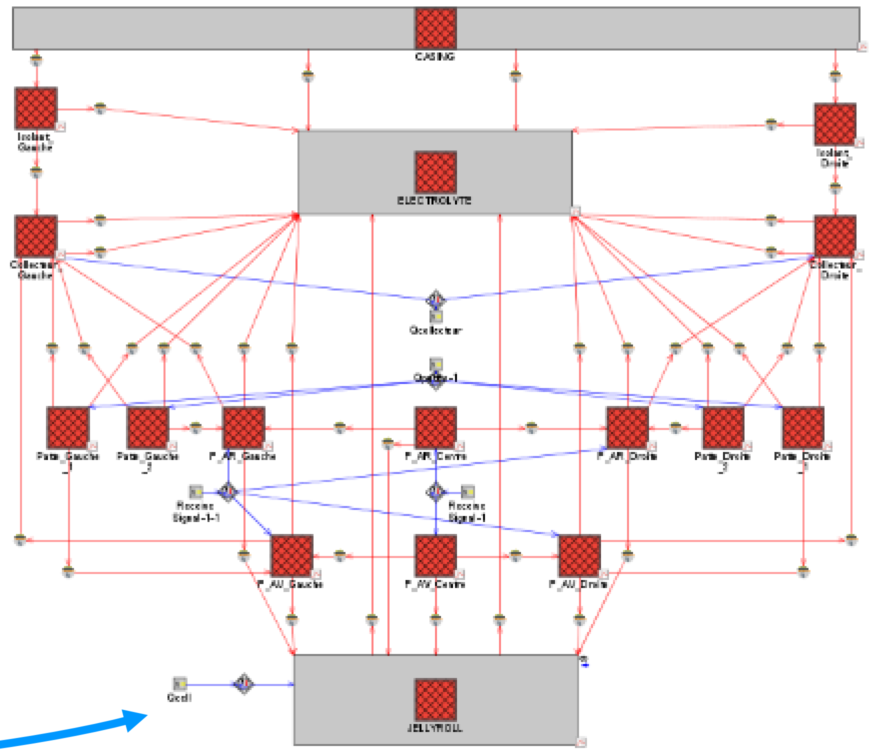
The complete model

Domains :

- ➢ Thermal domain (3D FE Thermal resolution)
- ➢ Electrical domain (0D Joule heating calculation)







<u>Electrical domain</u>

- ❑ Transfer heat production result
- ❑ Transfer back element temperature

<u>Thermal domain</u>

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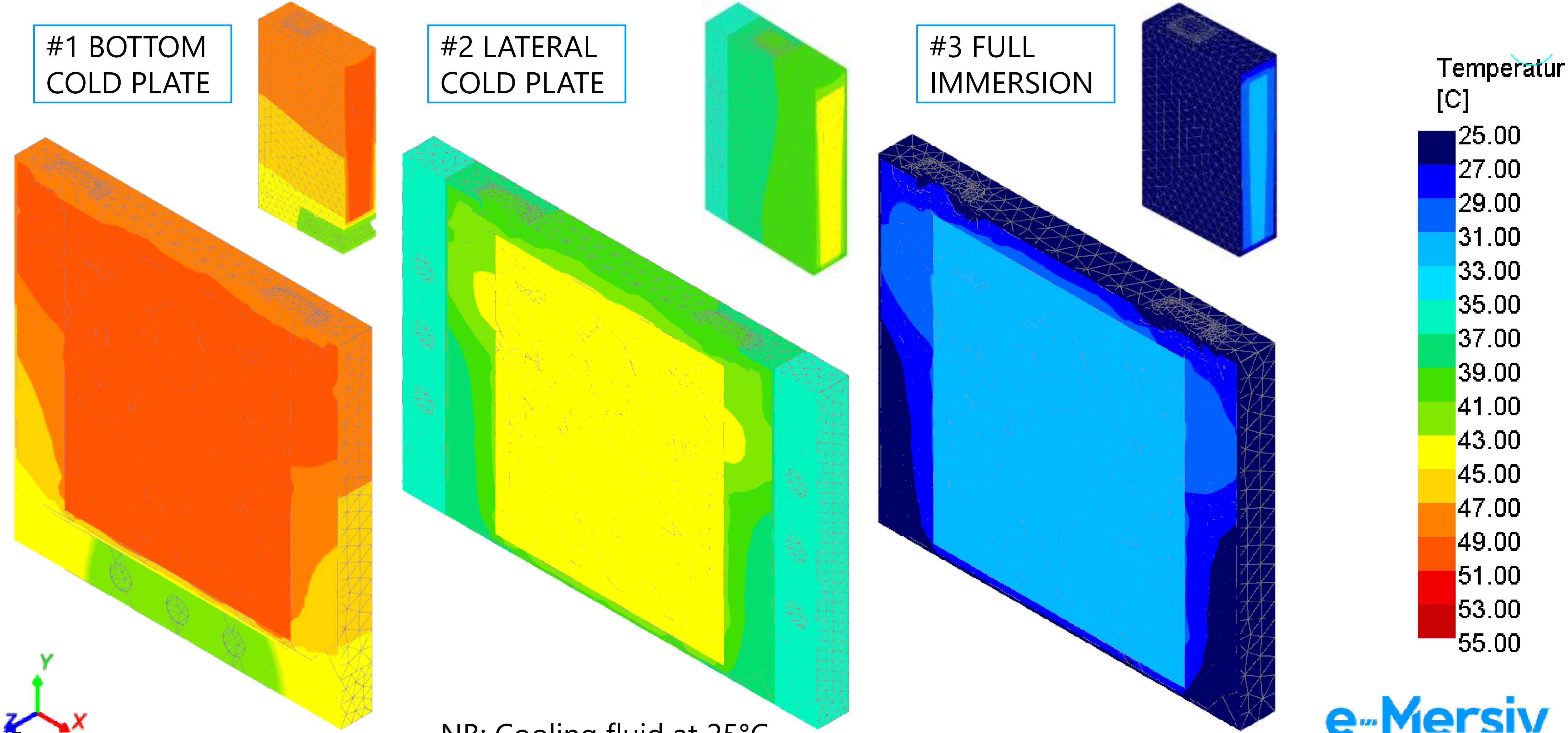
3D cell result
(t = End of simulation)

Scenario	*Cooling configuration*
#1	BOTTOM
#2	LATERAL
#3	FULL IMMERSION



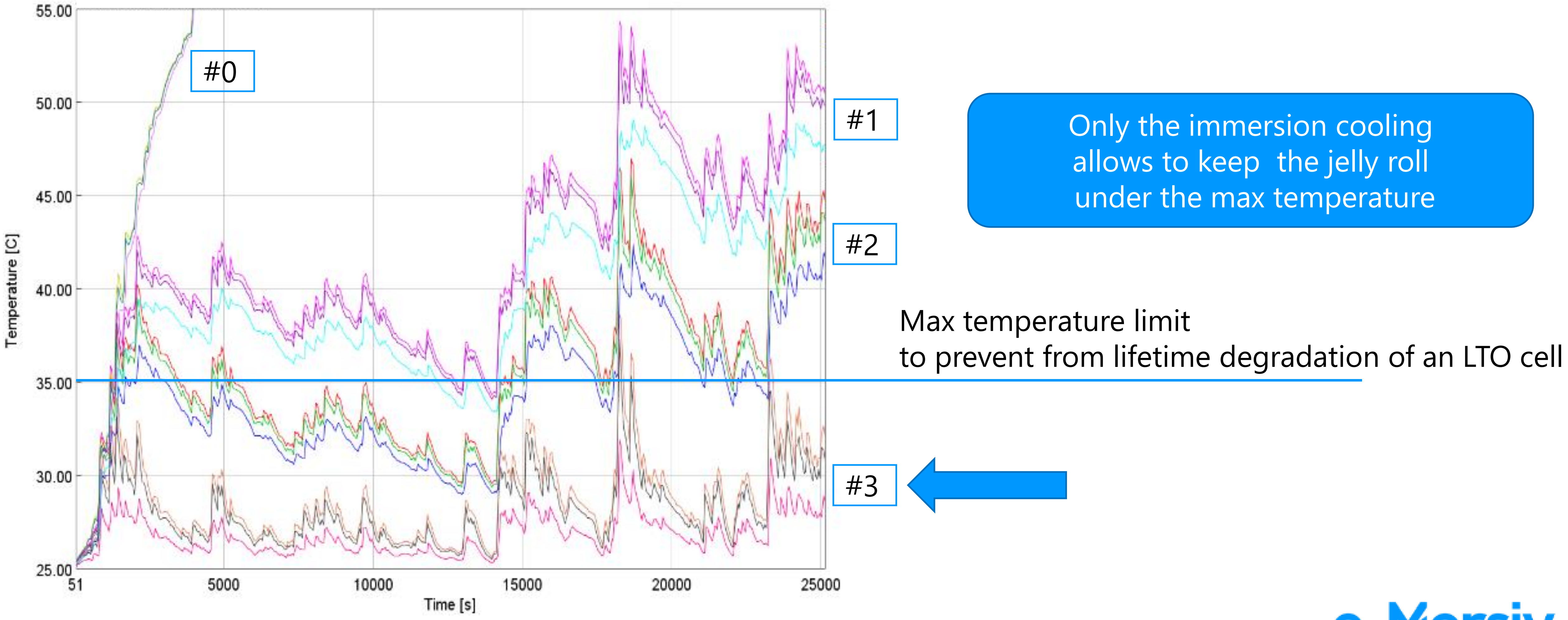
NB: Cooling fluid at 25°C

Jellyroll Temperatures

T-Max
T-Average
T-Min

Scenario	Cooling configuration
#0	NO COOLING
#1	BOTTOM
#2	LATERAL
#3	FULL IMMERSION

JELLYROLL TEMPERATURE [°C]



Only the immersion cooling allows to keep the jelly roll under the max temperature

NB: Cooling fluid at 25°C

Conclusion

Work done :

- 3D thermal simulation of a battery cooled by immersion
- Benchmark with a battery cooled by water/glycol cold plates
- Not presented: simulation of a thermal runaway propagation in both case

⇨ The appropriate cooling system was selected :
- Ability to simulate transient behavior with « normal » computers
(only 16Go RAM – full 3D CFD did not wort out – early trials led to computer black out !)

⇨ The module design was enriched thanks to the simulation
- sensitivty studies on parameters (intercell distance, flowrates, fluid viscosity, ...)

⇨ Prior to do destructive tests, the thermal runaway behavior was checked

Thanks for your attention !

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