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Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Kalogiannis, T., Stroe, D.-I., Nyborg, J., Nørregaard, K., Christensen, A. E., & Schaltz, E. (2017). *Incremental Capacity Analysis of a Lithium-ion Battery Pack for Different Charging Rates*. Poster presented at 231st ECS Meeting, New Orleans, LA, United States.

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Incremental Capacity Analysis of a Lithium-ion Battery Pack for Different Charging Rates

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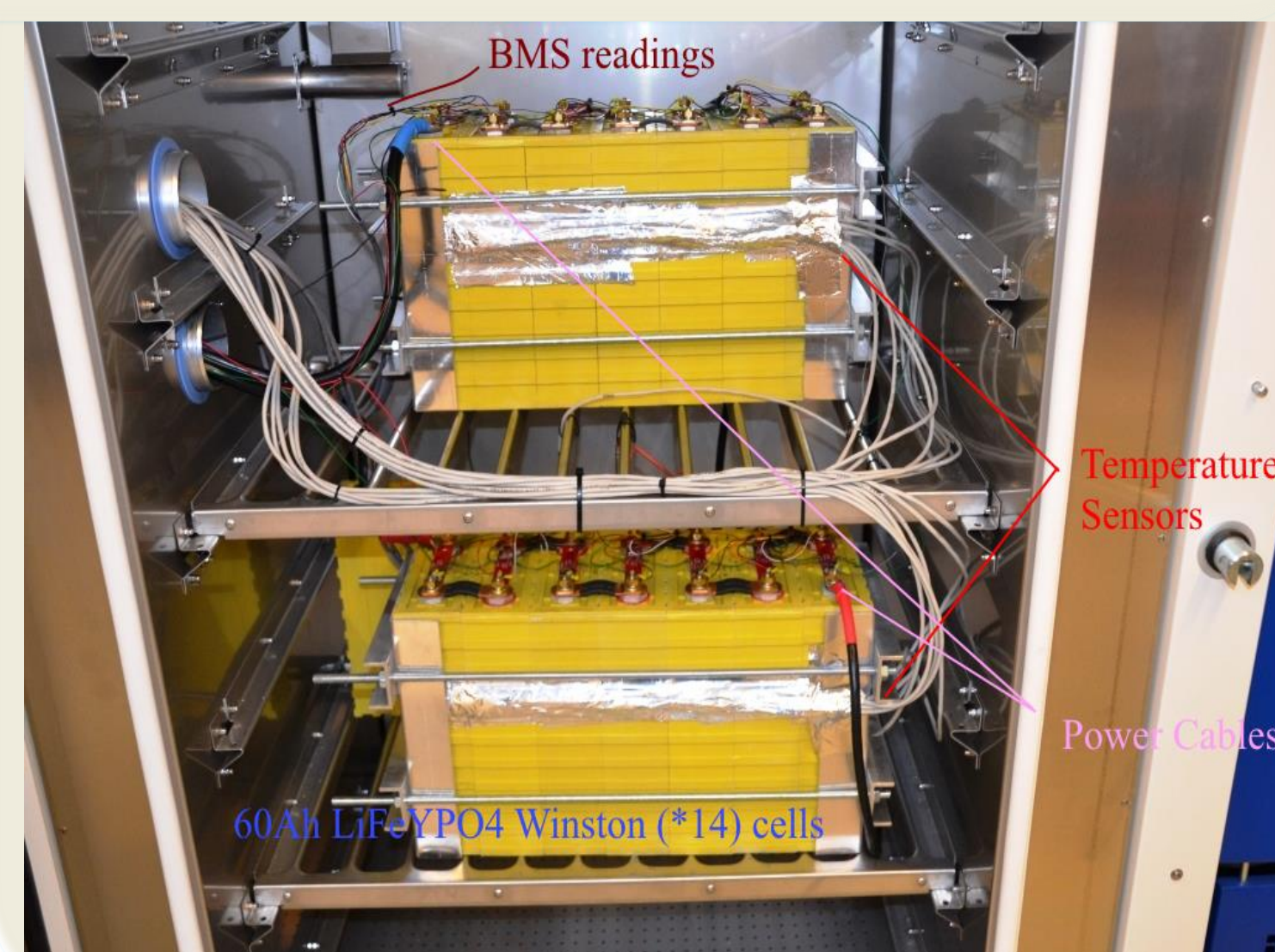
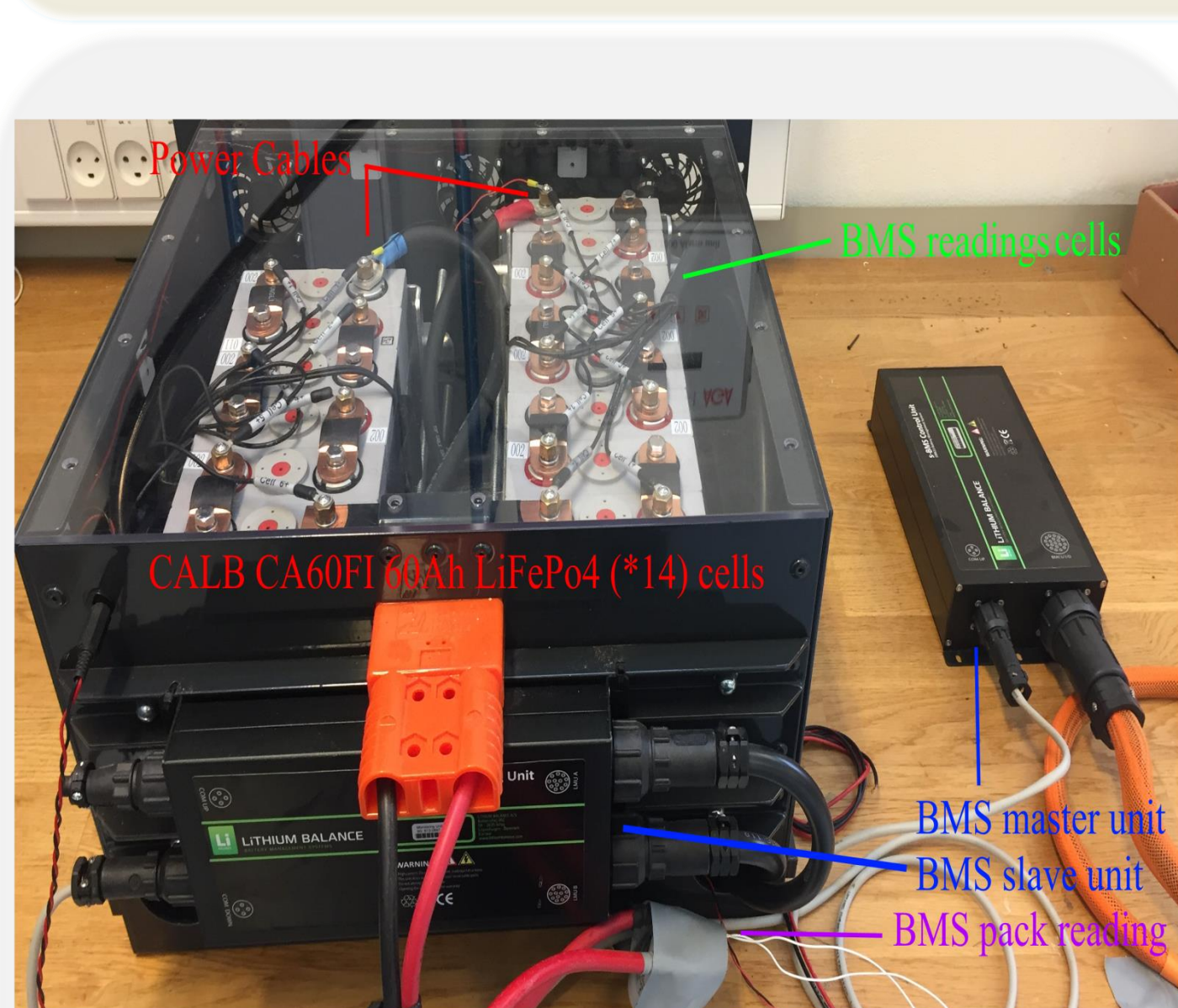


Motivation

Incremental Capacity Analysis (ICA) is a method used to investigate the capacity State-of-Health (SoH) of battery cells [1]. The aim of this poster is to present the challenges for implementing the ICA technique for battery packs, here consisted of 14 cells, by means of different C-rates (C/10, C/6 and C/5) and for several temperatures. LFP chemistry based cells are connected in series to build the packs, for either 60Ah and 160Ah.

Experimental Setup

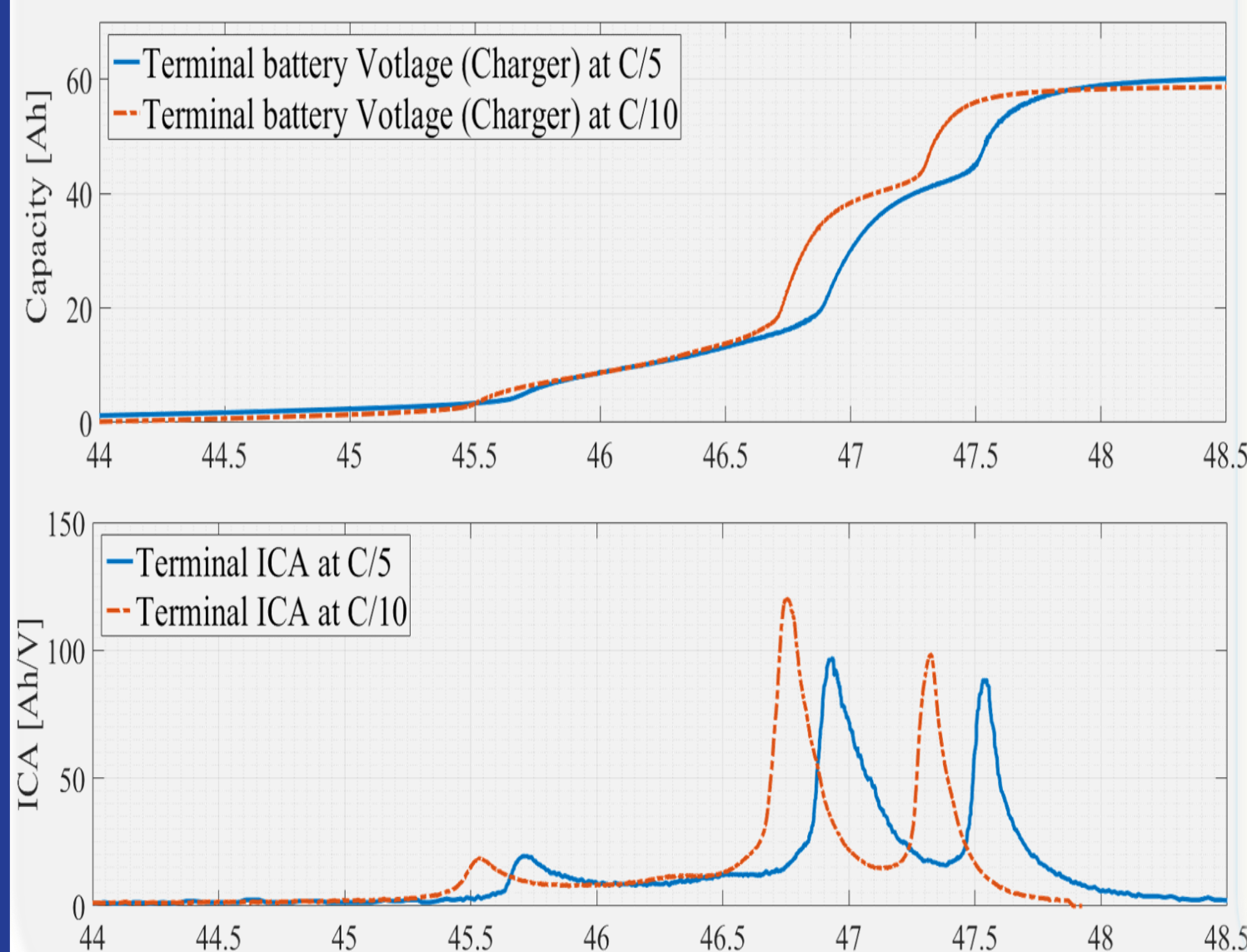
14*Winston 160Ah LiFeYPO₄ cells at C/6 between 5° and 30°C



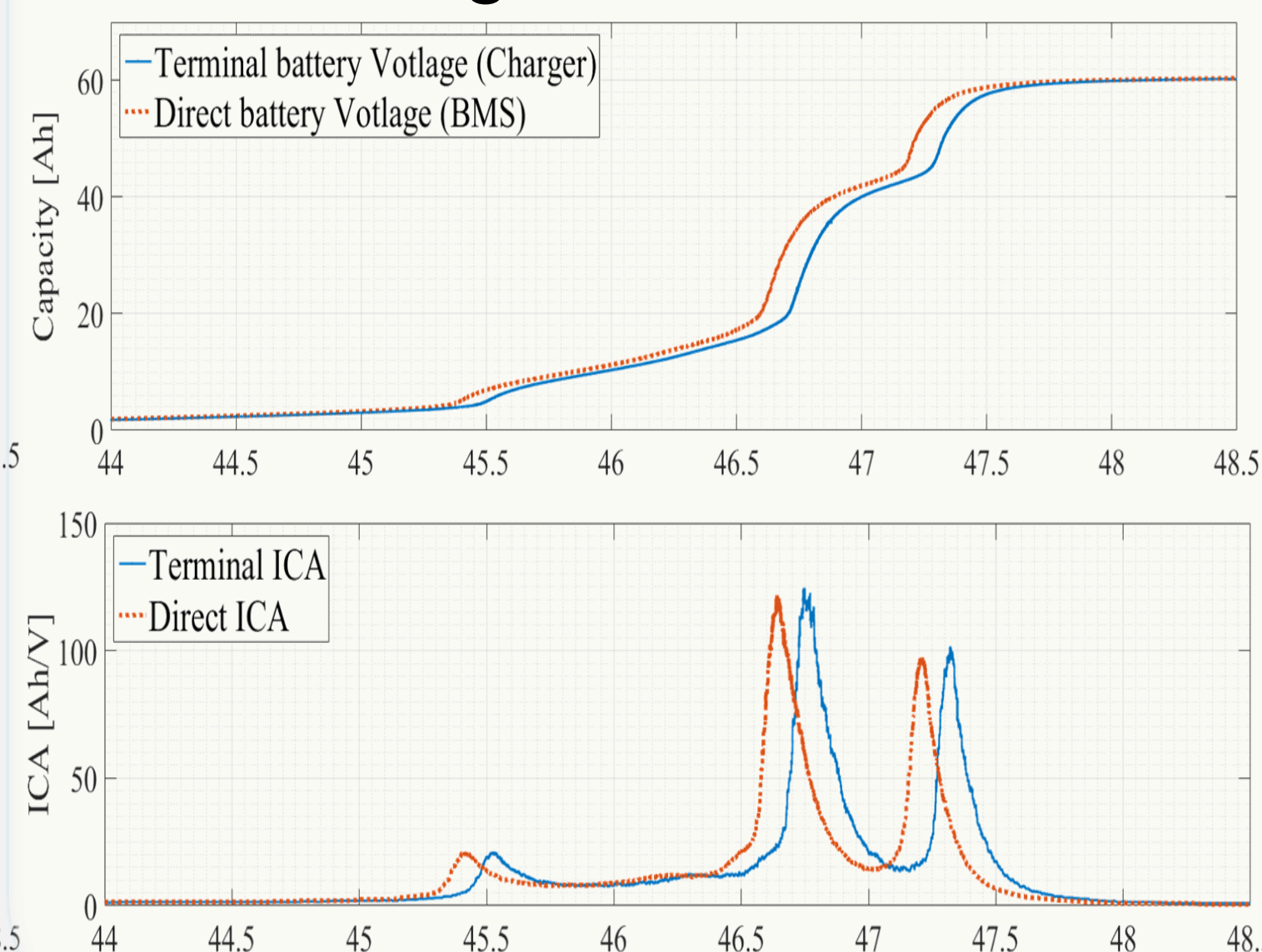
14*CALB 60Ah LiFePo₄ cells at C/5 and C/10 charge current rate

Direct & Terminal ICA

▪ **Charge Voltages:** at C/10 & C/5



▪ **Charge Voltages:** at C/10 for Charger & BMS



ICA Method

▪ **Incremental Capacity Analysis:**

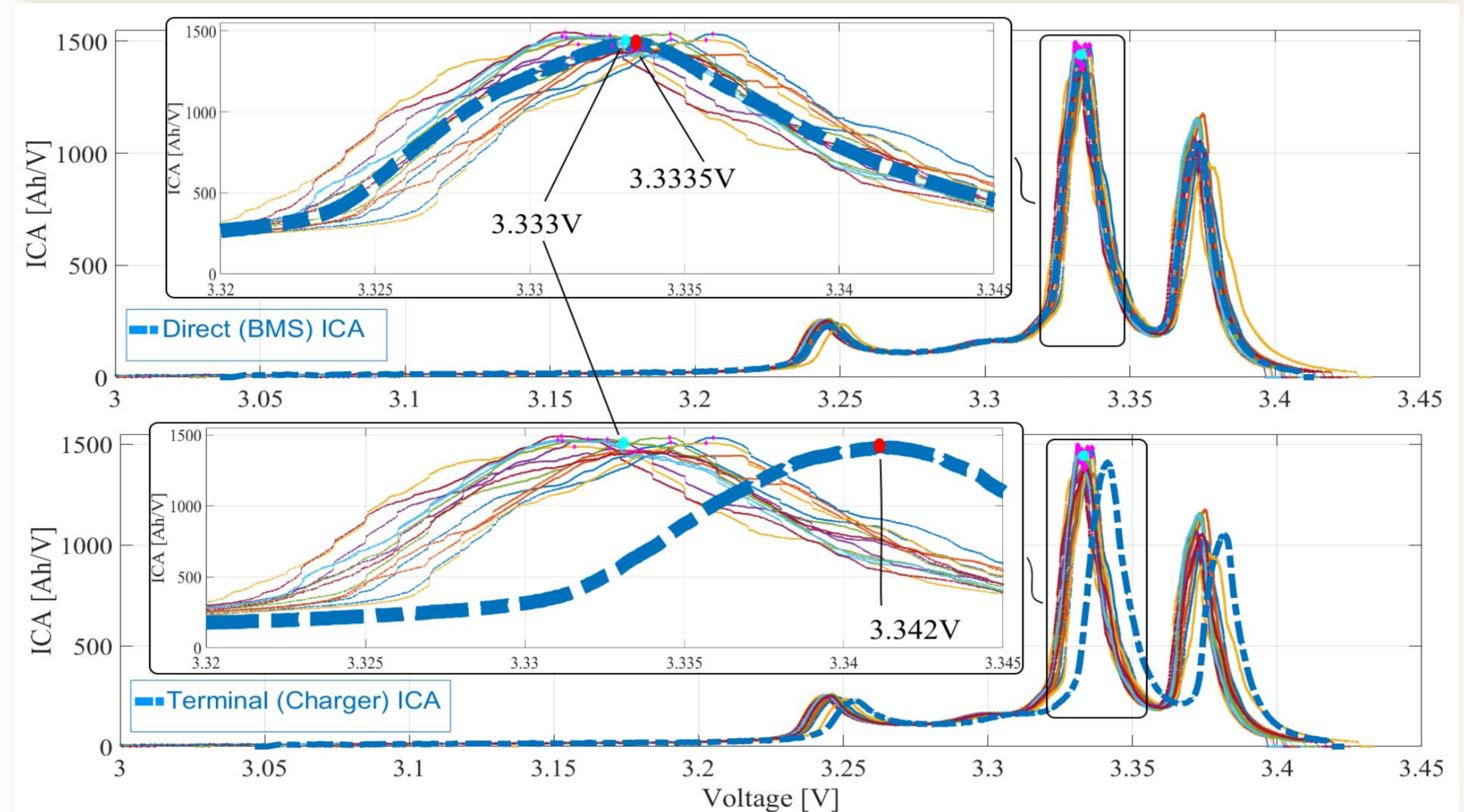
$$IC = \frac{dQ}{dV}$$

▪ At a chosen ΔV (5~25mV) [2]

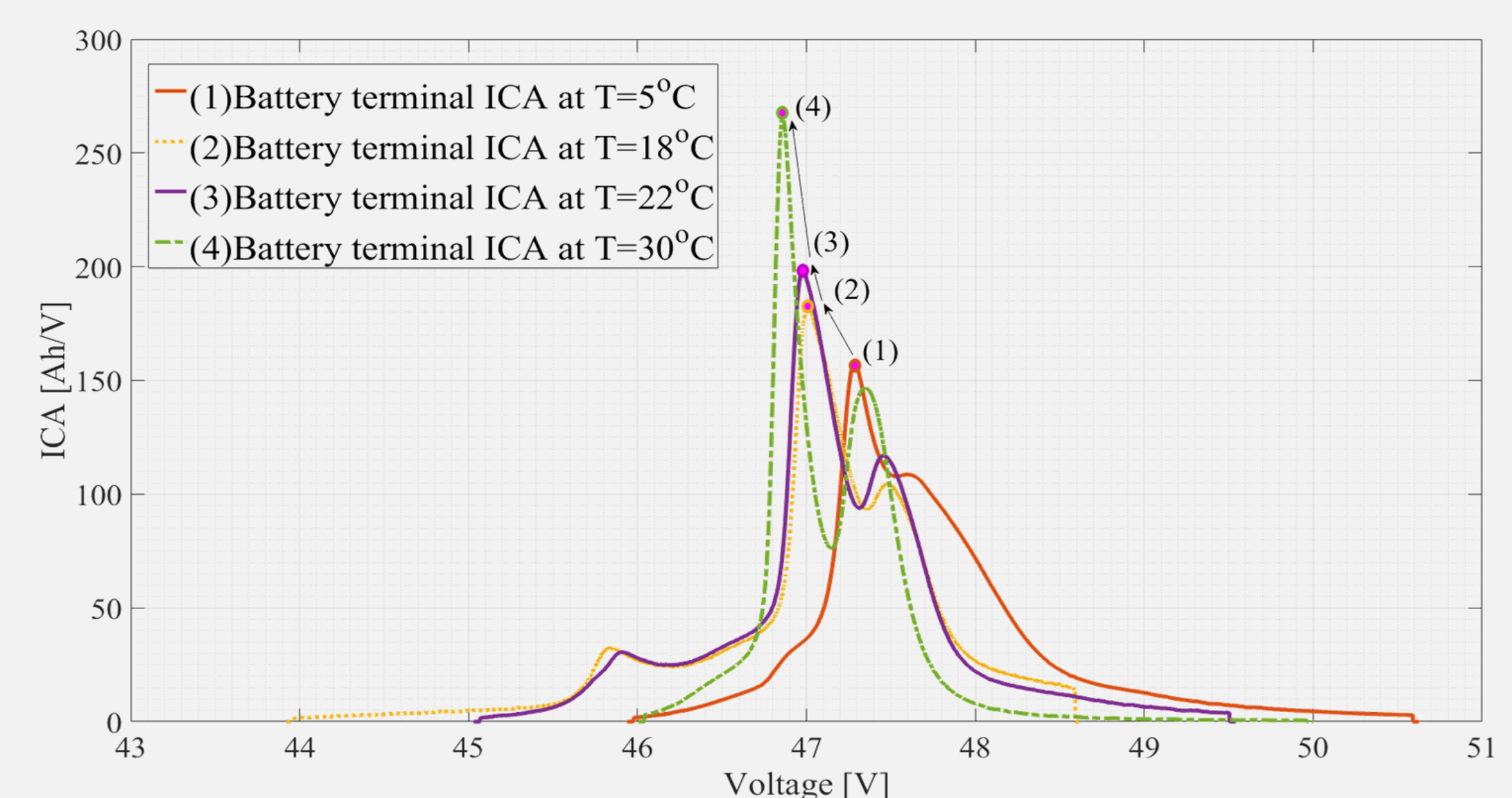
- Several approaches in literature for wide range of chemistries, capacities and cell designs [3]
- For many different C-rates and temperatures [4]
- Significance at a battery pack level not yet established
- Smoothing of raw data and filtering of charge/discharge capacity curves, to achieve an identifiable and unique IC peak

Results

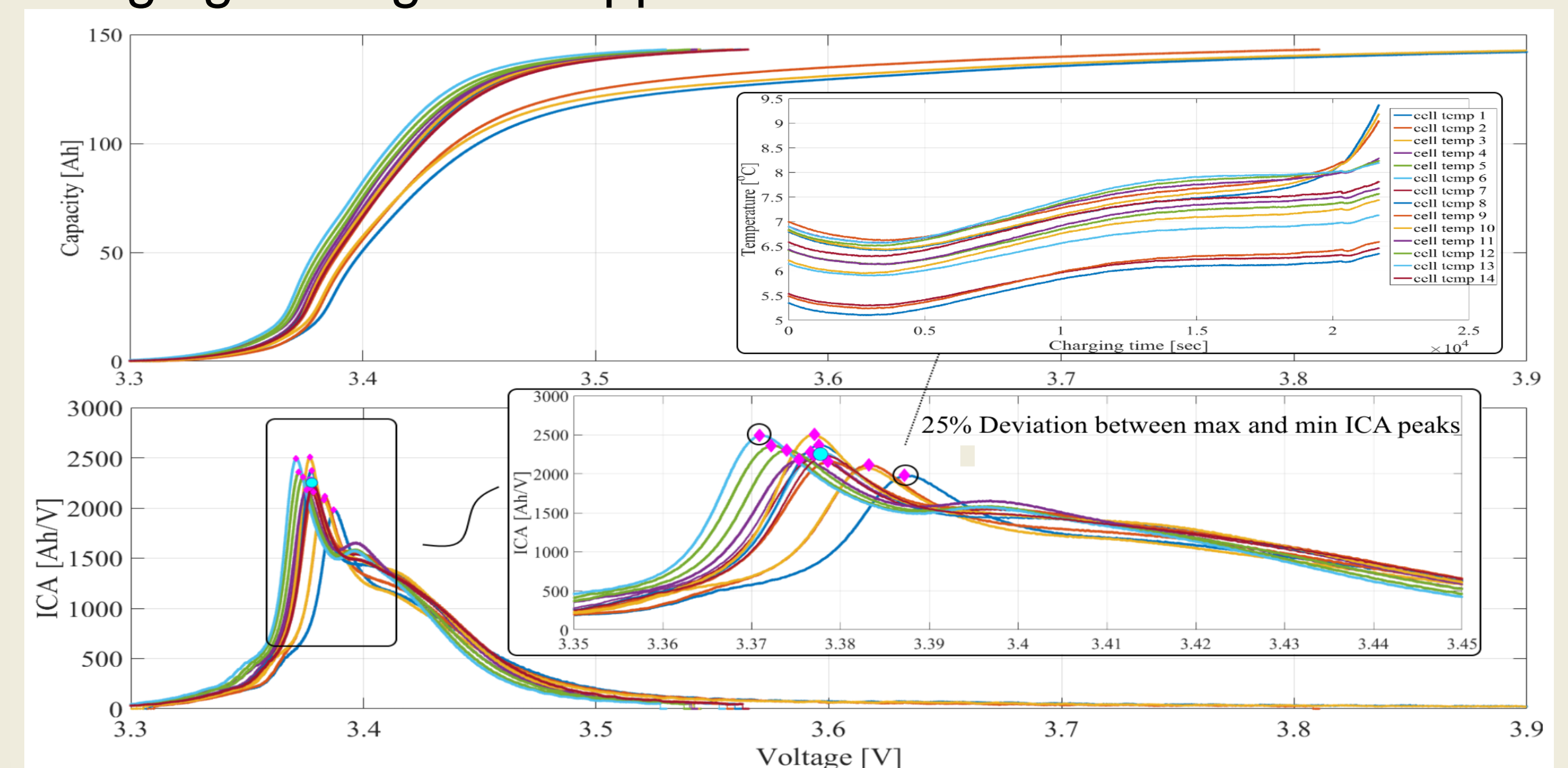
- **Direct ICA:** Less than 1mV deviation to the averaged cells ICA
➢ Accurate cell capacity SoH estimation based on pack readings
- **Terminal ICA:** Approx. 10mV deviation to the averaged ICA



- Terminal ICA sees a higher impedance path compared to direct
- **Variable temperatures for C/6:** For the 160Ah battery pack. The peak moves to the lower voltage levels due to lower resistance, which is caused by a higher temperature



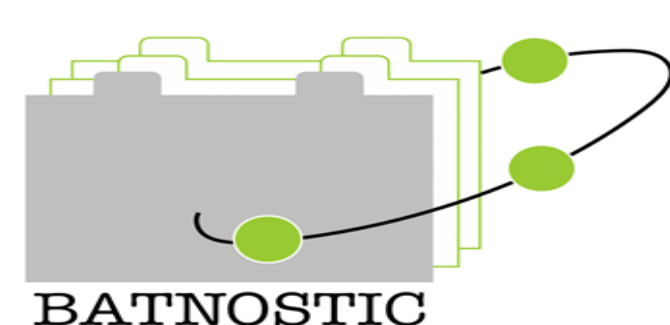
- ICAs influenced from temperature variations on the pack level
- **160Ah battery pack charged with C/6 at 5°C :** spread of the individual cells' peaks due to inactivity of balancing during charging. Charge is stopped when a cell reaches cut-off limit.



- ICAs are influenced from the cell to cell temperature variation

Acknowledgement

This work has been part of the BATNOSTIC project. Authors acknowledge the EUDP for providing financial support, the Danish Tech. Institute for conducting the battery pack tests and Lithium Balance A/S for providing the BMS.



References

- [1] M. Dubarry et al., Electrochem. Solid-State Lett., **9**, A454–A457 (2006).
- [2] X. Han et al., J. Power Sources, **251**, 38–54 (2014).
- [3] M. Safari and C. Delacourt, J. Electrochem. Soc., **158**, A1123–A1135 (2011)
- [4] C. Weng et al., J. Power Sources, **235**, 36–44 (2013)

Conclusion & Future Work

- The additional Z path, the temperature variations and the C-rates must be considered for ICA on a battery pack.
- Terminal ICA is not deriving the actual capacity SoH of the cells.
- Outlook: Lifetime experiments at pack level under certain conditions.