

Impact of Parallelization on Li-ion Battery Module Performance and Degradation

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Background

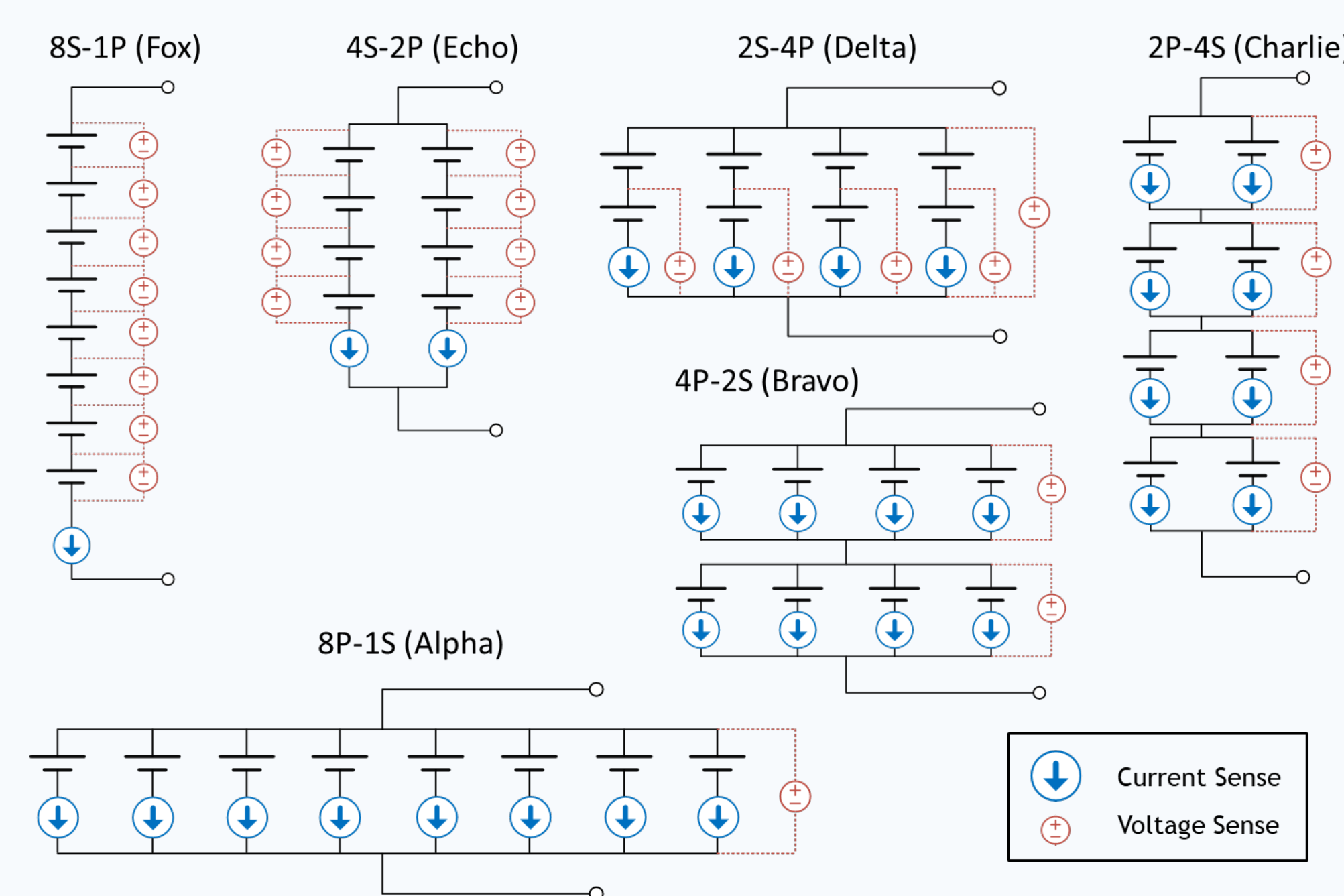
- Most battery cycling studies take place at the single cell level, but data needs to be collected across battery scales (including modules) to understand and close the systematic gap in performance between cells and systems
- Additionally, new power electronics topologies enable lower voltage battery systems and allow us to rethink optimal battery module configurations

Motivating Questions

- How do different module configurations (series versus parallel) impact battery performance and degradation?
- How does aging of a cell in a given module configuration compare with aging results observed in single cell studies?
- Given results to the questions above, how can we leverage new battery configurations or converter topologies to force cell performance closer to the ideal results indicated by cell-level studies?

Module Cycling Methodology

We explored all series and parallel combinations of an eight-cell module. Well-matched cells were selected from a lot of 400 3 Ah 18650 NMC cells. Module boards had cell-level current (Hall effect sensors) and voltage monitoring. Cycling was done at 25 °C, with 200 cycles at mild (0.5C/0.5C, 2.5-4.1V per cell) and 200 cycles at aggressive (0.5C/1.5C, 2.3-4.2V per cell) conditions without balancing. The program moved on to the next step once any cell in the module reached the voltage limit. This was completed with two sets of cells.

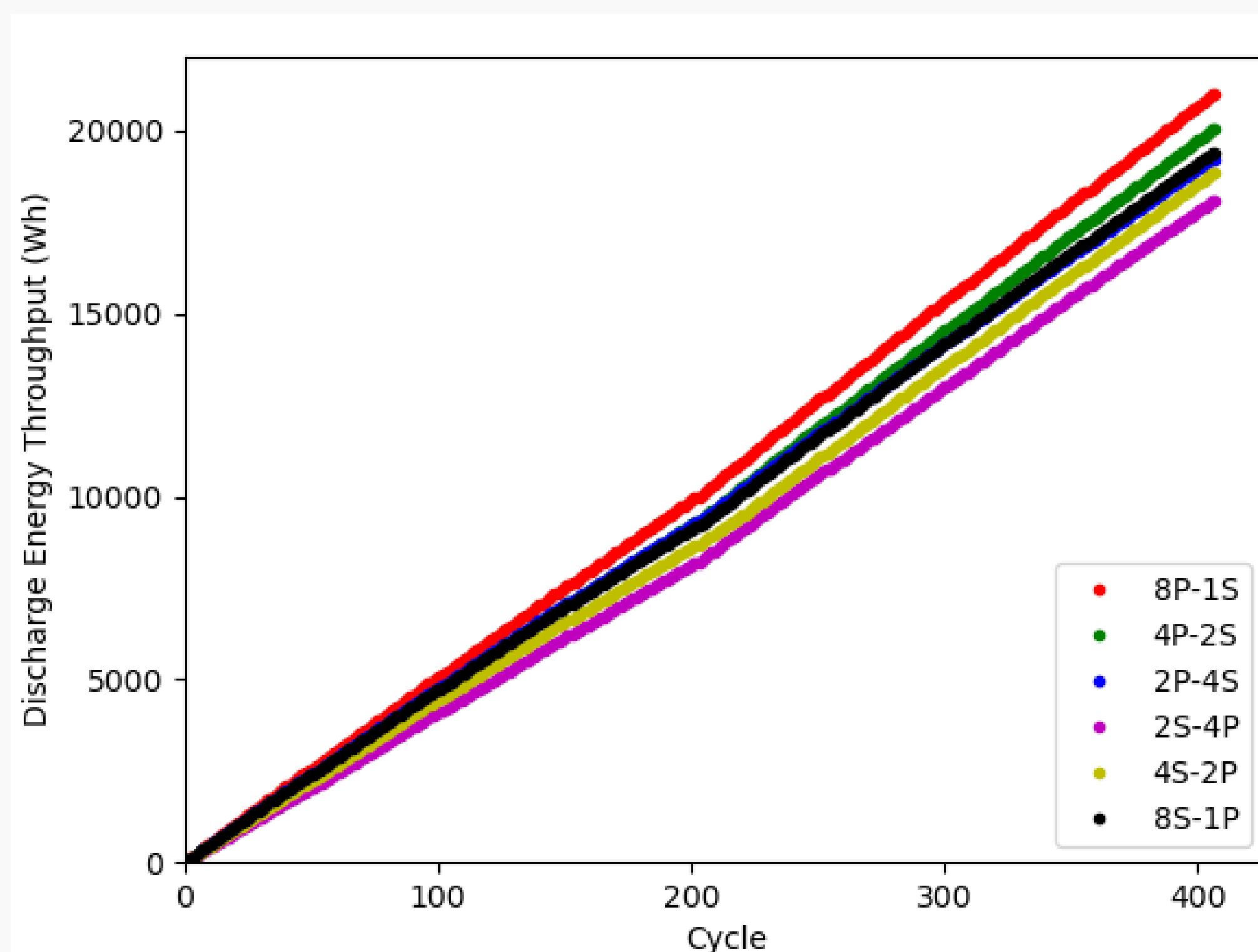


Module Configurations



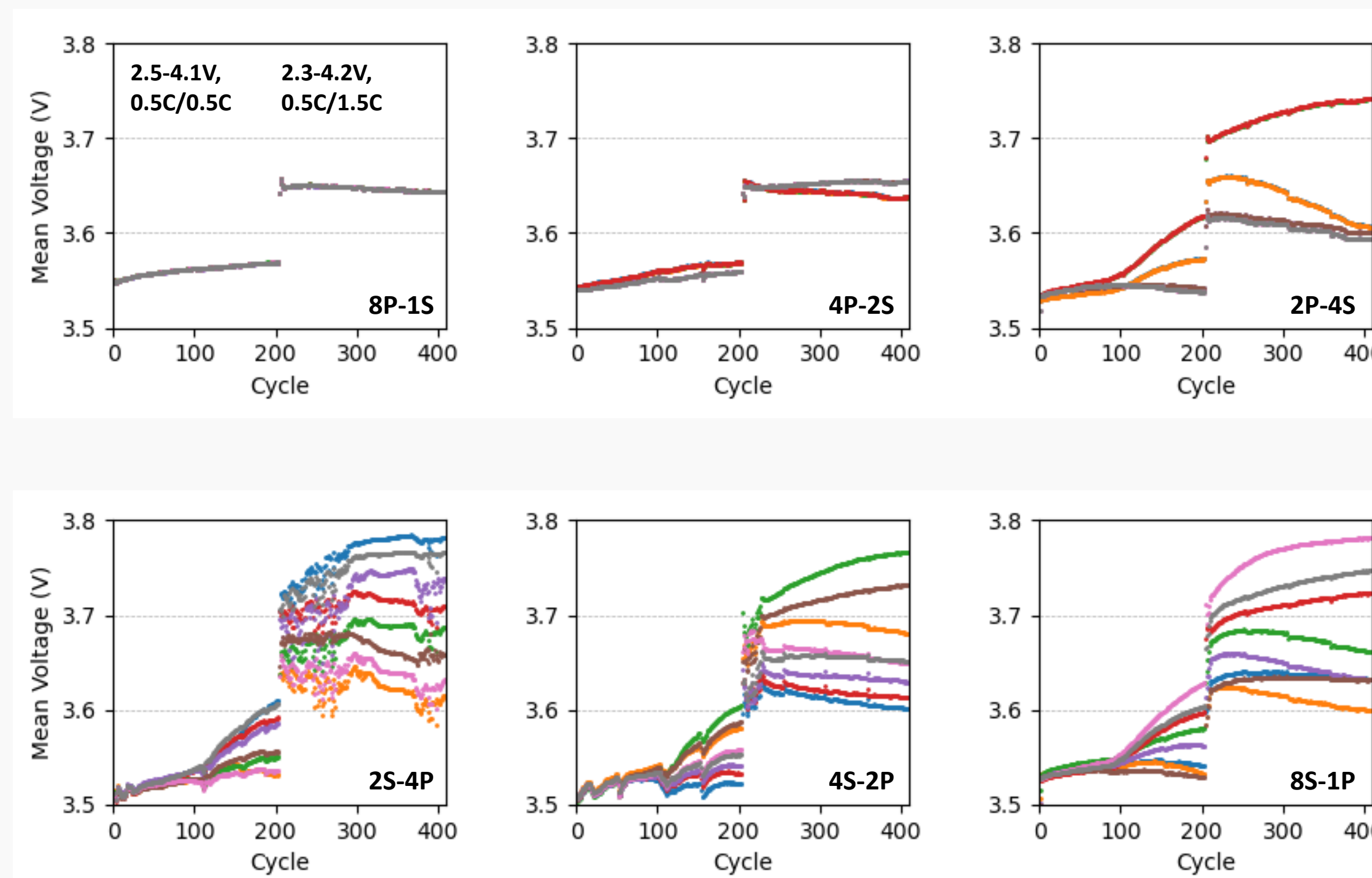
Representative Module Board

Discharge Energy Fade



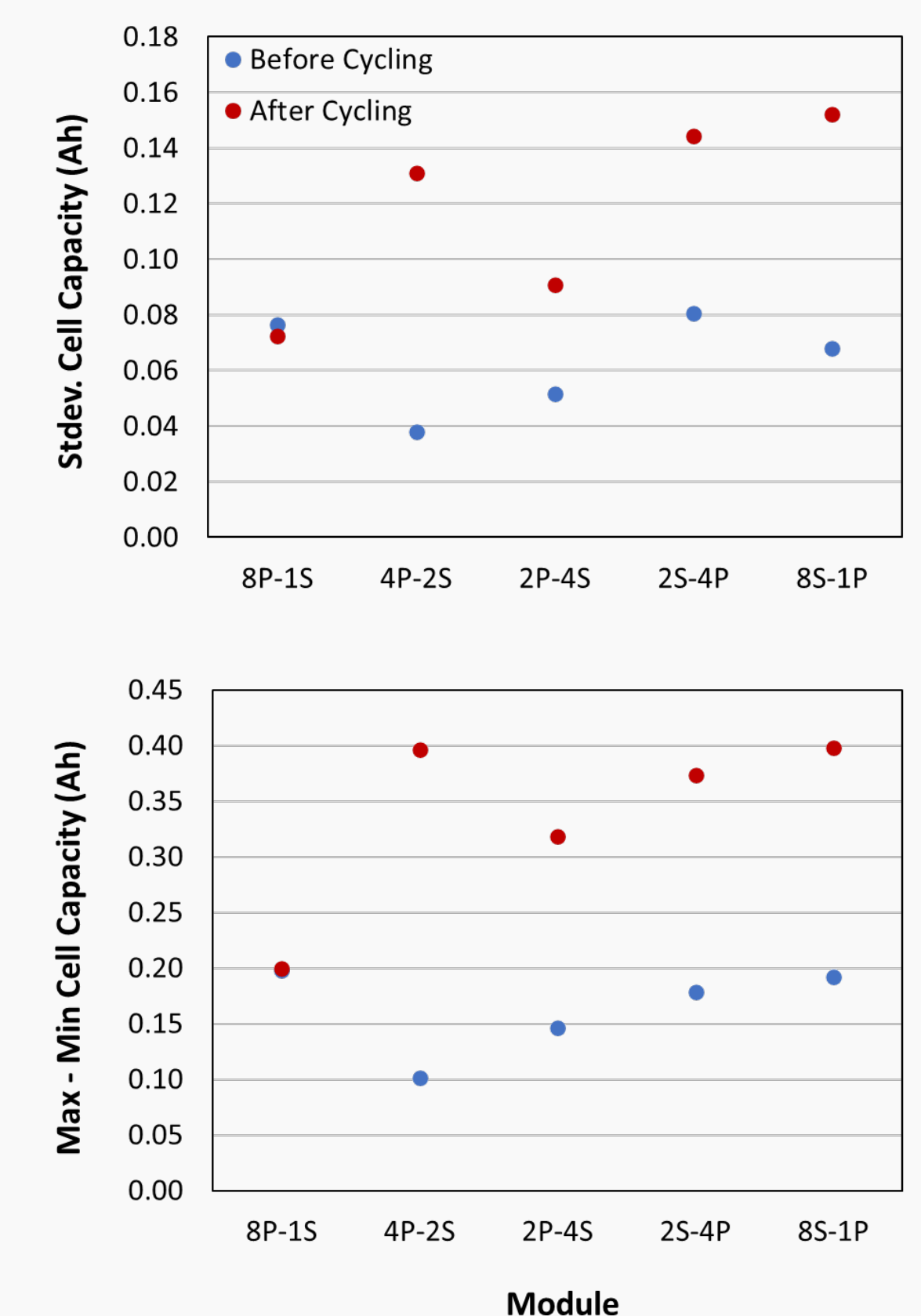
After 400 cycles, parallel modules show up to 15% higher energy throughput

Voltage Divergence



Lower discharge energy throughput in more series configurations is due to cell-level voltage divergence

Single-Cell SOH Convergence



Fully parallel configuration reduces variation in cell SOH

Conclusions

- Generated broadest module cycling dataset in open literature
- Parallel modules show a higher energy throughput (in absence of balancing) due to cell-level voltage divergence in series configurations
- A fully parallel configuration can also minimize divergence in the state-of-health of individual cells in a module

Future Work

- Collaboration with ORNL on modeling to understand the underlying physics
- Repeat experiments with another set of cells (LFP)
- Complete module cycling experiments with real power converters (e.g., with current ripple) and a battery management system